Report from

The 1984 Workshop on Advanced Technology for Building Design and Engineering

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Building Research Board
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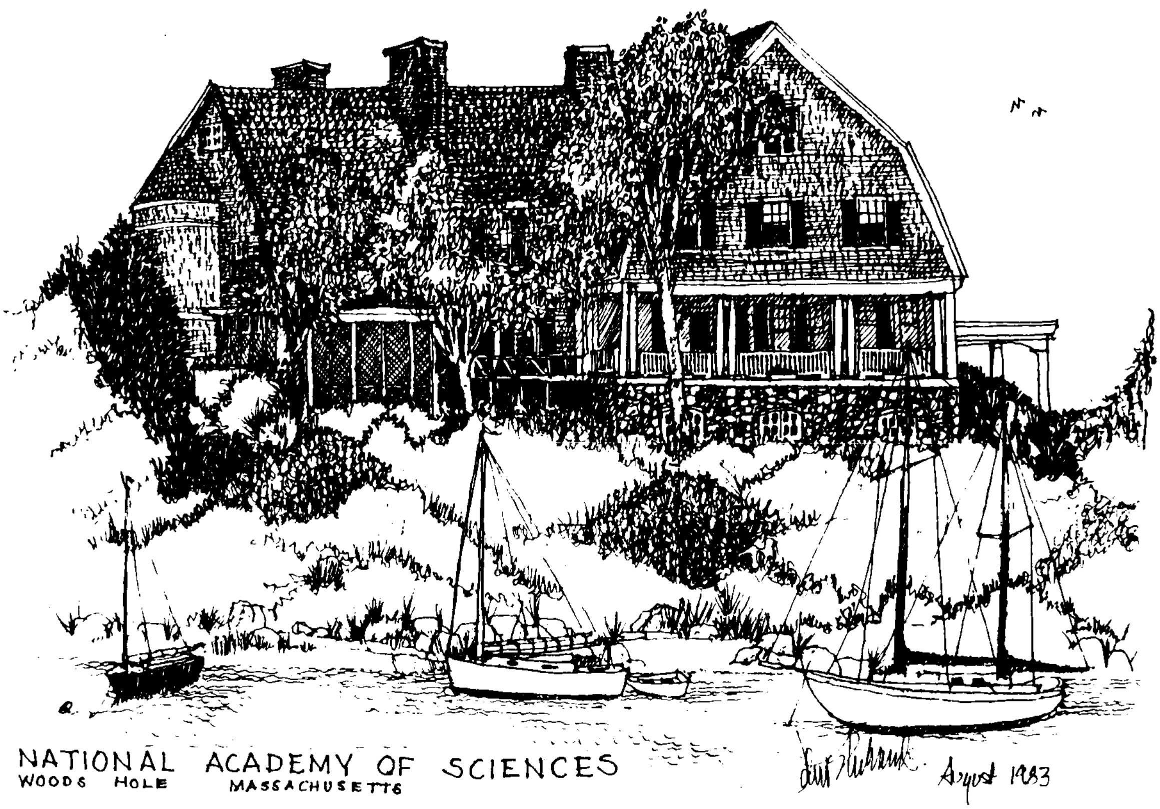

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This report was prepared as part of the technical program of the Federal Construction Council (FCC). The FCC is a continuing activity of the Building Research Board (formerly the Advisory Board on the Built Environment), which is a unit of the Commission on Engineering and Technical Systems of the National Research Council. The purpose of the FCC is to promote cooperation among federal construction agencies and between such agencies and other elements of the building community in addressing technical issues of mutual concern. The FCC program is supported by 14 federal agencies: the Department of the Air Force, the Department of the Army, the Department of Commerce, the Department of Energy, the Department of Health and Human Services, the Department of the Navy, the Department of State, the Federal Emergency Management Agency, the General Services Administration, the National Aeronautics and Space Administration, the National Endowment for the Arts, the National Science Foundation, the U.S. Postal Service, and the Veterans Administration.

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OVERVIEW

Advanced technology for building design and engineering has been the focus of a National Research Council committee since 1982 when, at the request of the Federal Construction Council, the Advisory Board on the Built Environment (now the Building Research Board) organized an advisory committee to examine the long-range implications of how advanced technologies will affect future design, construction and management of facilities. The purpose of this committee is to assist federal agencies responsible for building programs in planning for the use of new, computer-based technologies by providing an informed assessment of the state of the art and its evolutionary direction.

This committee invited several other experts to join it at a workshop held in August 1983 at the National Academy of Sciences Study Center in Woods Hole, Massachusetts. Participants at this first workshop, charged with the challenge to develop a conceptual framework for the integration of computer-based technologies in the building process, found that "much valuable data associated with the design, construction and operation of a facility are lost during its life span." The workshop participants stated that these lost data could potentially be used to improve the building process by providing the information needed for improving the performance and responsiveness of future designs, and for bringing about a reduction in the life-cycle costs associated with new facilities. The workshop concluded that efforts should be made to explore the development of an integrated computer data base that would be available at all stages in the life of a building project.*

This idea of an integrated computer data base became the core of the 1984 workshop. As in 1983, the committee invited other experts to Woods Hole from June 17-22, 1984, to focus on the conceptual framework of an integrated computer data base that spans the life cycle of a building. Participants were asked to examine data-base requirements

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*A Report from the 1983 Workshop on Advanced Technology for Building and Engineering, National Academy Press, Washington, D.C. 1984.

during the programming and planning phase, the design and engineering phase, the construction phase, and the facilities management phase. The results of their efforts is the subject of this report.

ORGANIZATION OF THE WORKSHOP

Thirty invited participants attended the 1984 Workshop on Advanced Technology for Building Design and Engineering. Architecture, engineering and computer sciences were the primary disciplines represented. Participants came from federal agencies, universities, architecture and engineering firms, computer companies, and research organizations. Biographical sketches of the participants are given in Appendix I.

Participants divided into three working groups during the workshop. These were:

1. Considerations for Data Capture. This group addressed questions about data capture throughout the entire life span of a building. This group consisted of C. Patrick Davis (chairman), Jack Enrico, Robert Furlong, Kenneth Goodwin, Ronald King, Robert Mahan, Edward Popko, David Skar, Peter Smeallie, and Robert Tilley.
2. Project Data Utilization Interfaces. This group considered the range of interface issues that must be addressed before an integrated data base for the building process can be developed. This group consisted of Harold Borkin, Alton Bradford (chairman), Lawrence Dyer, Richard Field, Fred Kitchens, Thomas Kvan, Shirley Radack, Kenneth Reinschmidt, and Leonard Simutis.
3. Data-Base Requirements for Analytic Methods in Early Design Decisions and Post-Construction Feedback. This group's objective was to examine the quality of building by maintaining the intent and philosophy of the building throughout its life cycle. This group consisted of Louis Childers, John Cook, Kenneth Crawford, Fred Lacerda, Douglas Nicholson, Mary Oliverson (chairwoman), Frank Peters, Neville Powers, and Richard Wright.

Each working group produced a report that was presented to the entire assembly on the last day of the workshop. These reports can be found in Part I of this document.

Selected participants were asked to give prepared presentations on data requirements at the various phases of the building process. These presentations provided the working groups with current examples of data base considerations during the planning and programming stage (Fred Kitchens), the architectural stage (Harold Borkin), the engineering stage (Richard Wright), the construction stage (Jack Enrico), and the facilities management stage (Douglas Nicholson). Texts of these presentations can be found in Part II of this report.

GENERAL FINDINGS

Workshop participants generally agreed that there is a need for the development and implementation of an integrated project data base such as the model developed by the interface working group (Figure 1).

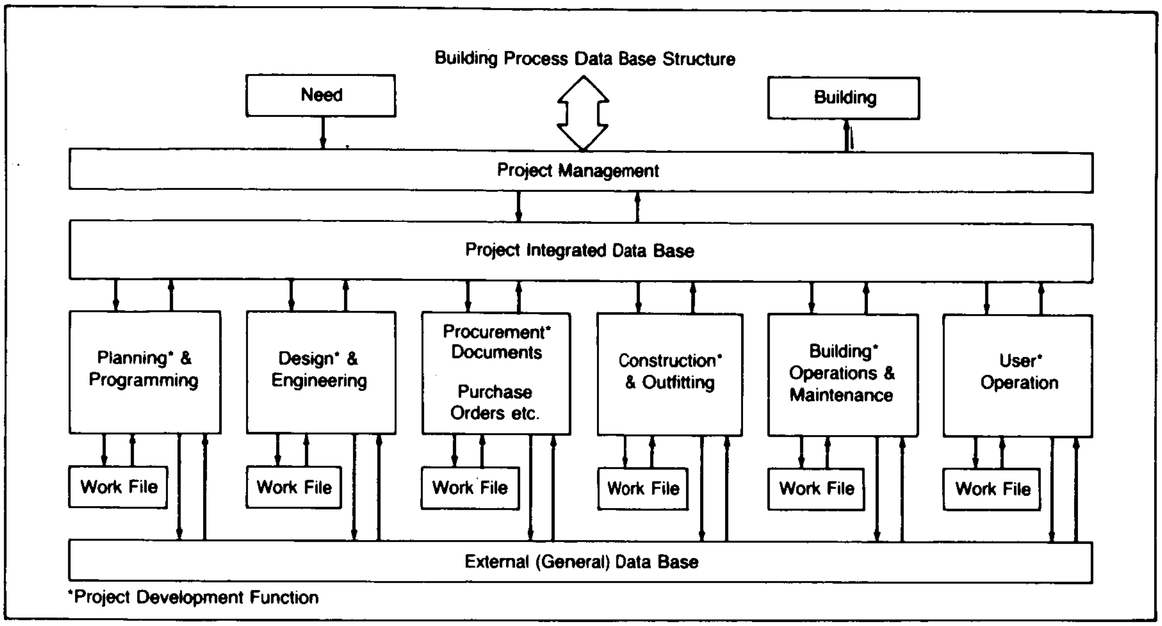

FIGURE 1 Integrated project data base.

This proposed model for an integrated project data base removes the interfaces between the phases of the building process and substitutes a data base to which common, usable data can be sent. A project management function has responsibility for managing the data base. Work files for each phase provide flexibility to the system. The external general data base represents those data bases that consist of data relevant to many projects (such as regulations, codes, and generally accepted design standards and engineering practices).

The integrated project data base will support all phases of the building project and will involve new ways of representing and exchanging data (such as building geometry and protocols for data exchange). The participants concluded that life-cycle cost considerations should provide the economic rationale for the building owner to invest in the development of an integrated project data base. The availability of an integrated project data base makes it possible to have more efficient facilities management that should result in savings to the building owner.

These, and other findings, are more fully explained in Part I of this report.

PART I

STUDY GROUP RESULTS

1

CONSIDERATIONS FOR DATA CAPTURE

The group was asked to consider questions about data capture throughout the entire building process. The group addressed the questions of who captures data, what data to capture, when to capture data, and why capture data at all.

INTRODUCTION

The 1983 Workshop on Advanced Technology for Building Design and Engineering concluded that much valuable data associated with the design, construction, and operation of a facility are lost during its life span. Much of the data could be used to improve the building process by (1) improving the quality of future designs in terms of performance and responsiveness, and (2) reducing the life-cycle costs associated with new facilities. As demonstrated in the findings of the interface working group (see Chapter 2), current practices provide little incentive for sharing data among participants in the building process. Someone in this process has to assume a leadership role to ensure that these valuable data are not lost.

This group believes that the building owner stands to benefit far more than any other participant and is in the best position to serve as an information resources manager for the data capture function. Only the building owner, who has control over the steps in the building process, can cause this change to take place in the industry. Figure 1-1 shows that close to 80 percent of the life-cycle costs of a facility are for operating purposes. Life-cycle cost considerations demonstrate that building owners will benefit and will drive the development process for an integrated project data base. It is the owners' ability to amortize the cost of data creation, collection, maintenance, and use over the life of the facility that will pay for the development and implementation of these systems.

Many independent participants are involved in the building process, each having a role that is performed at a specific point during the life of a facility. Each participant generates, reviews, and modifies data. Each also obtains and acts upon data generated by others. Data are lost, errors are introduced, and delays occur as needed information

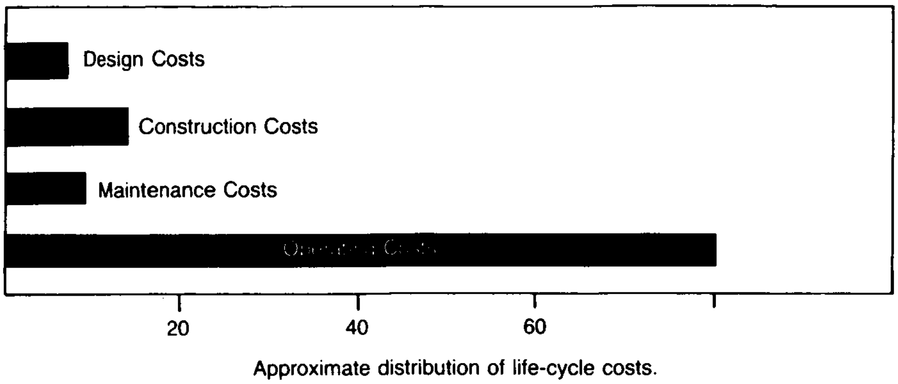

FIGURE 1-1 Building owner's life-cycle costs.

is located or regenerated. The linkage is particularly weak at the beginning and end of a project, that is, in defining the users' requirements and in determining whether the facility actually meets these requirements.

Participants in the building process generally do not have a clear understanding of or interest in the information needs of other participants. Consequently, the data actually transferred do not usually fulfill the needs of others. Data are compressed and passed on in an abbreviated form, or not passed on at all. In many cases, the information has to be regenerated, often repeatedly, during the project's life span. To prevent this loss, useful data must be captured when initially generated and made available to others.

Computer technology offers improved tools to aid the free flow of information among participants. Computer aids such as information storage, retrieval, modification, communications, and display can contribute significantly to reducing design and construction time frames and providing more responsive and efficient facilities.

This group hypothesizes that an integrated information resources management system that accumulates project data over the life cycle of a facility should provide significant benefits to the building owner. To do this, the informational needs of the various participants throughout the entire life cycle of the facility must be identified and captured. The following is a discussion of various considerations in capturing useful data.

ASSUMPTIONS

1. No major changes will occur in building process concerning the traditional relationships among owners, designers, contractors, users and other participants. As an integrated data base is developed for a project, the existing relationships may change to take more complete advantage of the available data.

2. By ensuring data consistency and possibly eliminating data redundancy, an integrated data base will have economic advantages over the current process.

3. Because computer technology is advancing at a rate faster than the building industry's ability to apply it, the technology to capture the required data will be available in whatever form may be necessary.

APPROACH

While the building process has a clear objective--to provide a facility to the owner that meets the requirements for use--the data requirements within this process are not as clear. The large number of participants in this process complicates the question of what data to capture. Each participant develops a large amount of data, some of which are valuable to subsequent participants. Frequently, participants are autonomous organizations brought together through separate contracts. Individual data users must identify the "pass-through" data that should be captured and "handed-off" to subsequent participants.

Today's structured techniques for identifying and defining data require that participants analyze their requirements individually and collectively. Capturing these data can be approached using a three-level analysis. First, the processes involved in the major phases--planning and programming, design and engineering, procurement and specifications, construction and outfitting, operations and maintenance, and user operations--are identified. Second, the applications that fall within each phase are defined. The applications should be modular so they can be tailored to the project requirements. Finally, the data required to support each application should be identified. These data requirements will be used to design the data base.

STRATEGY

This section describes a methodology for identifying specific data elements and data-base structures. These steps are important to the development of data-base systems that have a high degree of consistency and integrity.

A building can be described as an integrated entity that encloses space and has both form and function for human use. To build a useful building, it is necessary to have an integrated process that leads from the initiation of a requirement for a new building through its eventual occupancy and use. Because this process is complex, it is necessary to use an appropriate division of labor.

To make the process manageable, it is divided into specific phases, phases into work packages, work packages into tasks, and so on. At each level, or division, of work we assign specialists to perform the detailed work.

Each functional work area is a consumer and producer of both tangible and intangible objects. Material is transformed and a product is produced. Information is consumed and information is produced. In each case, some value is added to the tangible or the intangible object. When the task is completed, the information or product is turned over to another group for further action.

The building process is a complex web of interconnected participants. The computer is currently used to deal with a single work area or with an isolated function. As more computers are introduced, the information handling system becomes more and more fragmented. As computers proliferate, one becomes aware of the inefficiencies created by an isolated approach.

Building data are stored in a variety of computer systems by different participants in the building process. Data are re-entered into a computer at various times during the life cycle of the facility. At times, data cannot be entered and/or transferred because the various computer systems are incompatible, i.e., they have different data formats and/or electronic protocols. In order to solve these and other data-related problems, it is necessary to take a broad view, one that brings the building process into focus as a single, integrated process. We can envision a series of steps that make possible the integration of building process data into one integrated building information system.

The key to the development of such a system is to create an information resource management (IRM) architecture. In the same sense that the architecture of a building describes an integrated structural environment, an IRM architecture describes an integrated information environment. An IRM architecture will vary depending on the characteristics of a particular organization, the state of technology, the kinds of data, and whether the use is public or private. Generically, however, an IRM architecture consists of four distinct parts:

1. Applications architecture--the definitions of the functions and functional relationships that comprise the building process;
2. Data architecture--the identification of the entities and relationships that support the applications architecture;
3 Systems architecture--the definition of the structure and relationships of the hardware and software resources that support the data and applications architecture; and
4. Network architecture--the definition of the structure and relationships of communications and computing facilities.

Taken together, the four architectures make up an IRM architecture. The first two, applications and data, are relatively independent of the technology and are driven by the building process. The latter two are technology dependent, but are also closely related to the characteristics of the building process. For example, if the building process is geographically dispersed, then a geographically distributed systems architecture may be required with its associated network.

For this workshop, it is most appropriate to concentrate on the applications and data architecture.

Applications Architecture

Applications architecture can be derived from the description of the building process and can be described or defined in a number of ways. The most common method of defining applications is by developing a portfolio that describes the elements of a process in terms of inputs, outputs, and processing functions. In order to capture a process, a complete set of applications must be described. They should be described at a level that is roughly similar to the level of detail found in the programming phase of a building project. Enough information must be prepared to identify each application, locate it in the process, and determine its major inputs, outputs, and functions. If this is done properly, it should provide enough information to construct a crude data model at the next stage, the data architecture stage.

A significant barrier exists in that classical computer techniques teach the development of a comprehensive requirements analysis with detailed input, output, and functional (algorithmic) descriptions. To attempt to do so for an activity as large and complex as the building process would not be effective. Instead, a high-level architecture should be developed that can be successively refined in the same sense a building design is successively refined. In the past, the detailed requirements approach has been followed because computer software was hard-coded and not easily modified. Today, the computer resources are available that can be successively refined without major rewrites of the software. Table-driven software, generators (such as screen generators), fourth-generation languages, and relational data-base systems represent highly flexible tools.

Figure 1-2 provides an applications view at the highest level for the facilities management process. It identifies candidate applications areas. Further definition of these application areas is a needed next step.

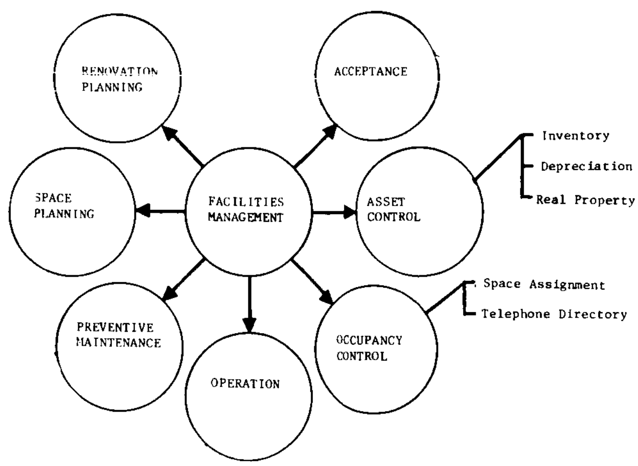

FIGURE 1-2 Applications architecture for facilities management.

Data Architecture

Figure 1-3 shows the process flow for the development of a data architecture. In order to generate a data architecture, one must map the building process and its applications architecture. Once the data

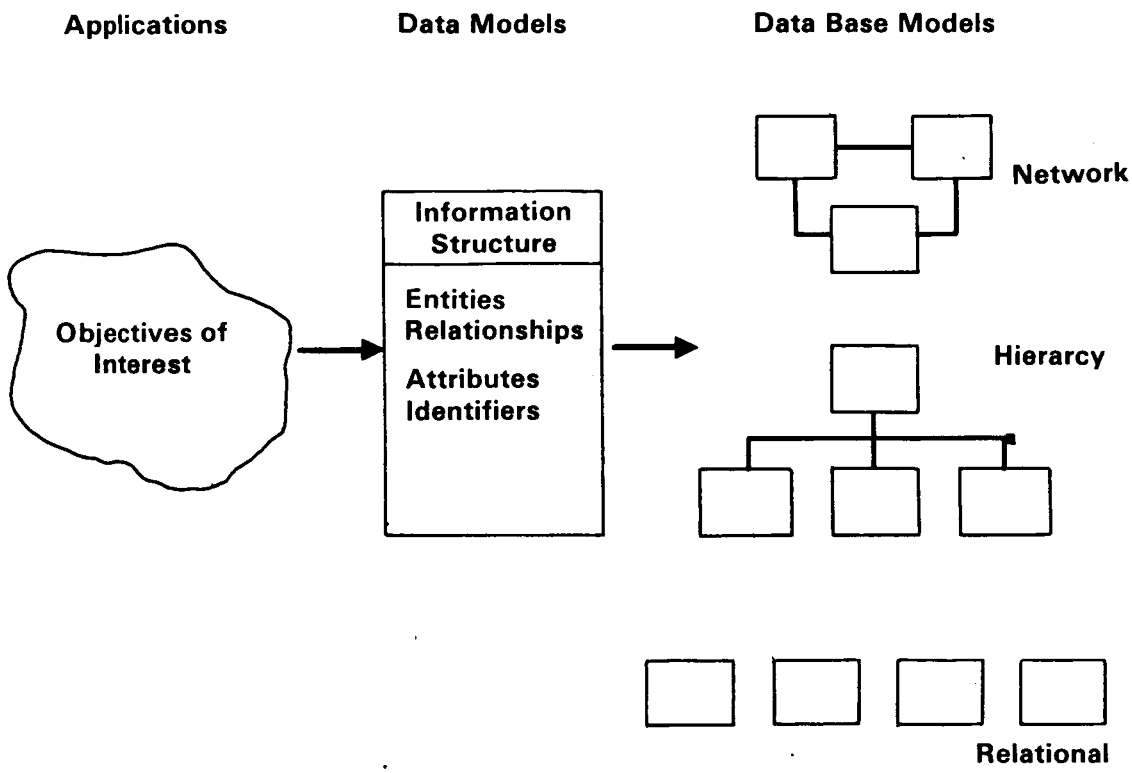

FIGURE 1-3 Data architecture.

architecture is established, a data base can be implemented. The important characterisitics of the process described in this figure are:

- The data modeling process is driven by the building production process and its associated applications. The model is as good as, or as bad as, the description of the application environment.
- The data model is independent of the physical implementation of the data base. It represents a logical structure that is independent of the technology. The user can elect to implement the physical data base in any one of the three data structures pictured as examples (network, hierarchy, or relational).

The purpose of the data model is to:

- Represent a logical information structure that reflects the building process;
- Identify the data elements to be captured; and
- Provide a mechanism for the normalization of the data. Normalization is a process that removes ambiguity from the data structure that would create implementation and use problems.

The approach described in Figure 1-3 is the use of entity relationship analysis. While this is an especially useful technique, it is not the only one that can be used. An entity is an object about which we wish to store information (e.g., a component such as a pump). A relationship defines the logical relationship between different entities.

In addition, we can assign attributes to entities. If, for example, a pump is an entity, then attributes of interest are size, identifying part number, manufacturer, and so on. Data elements are specific instances of attributes. An identifier is an attribute with the special quality of being unique. Part number would be an example of an identifier.

After structuring a data architecture, one can begin to develop a list of data elements to be captured. The data elements are generally defined in a data dictionary in terms of attribute name and description. The data dictionary serves to focus discussion on the characteristics of entities, and is used to identify what to capture. The main point is that the development of a data architecture is essential to the development of an integrated data system.

DATA DICTIONARY

General Data Bases and Project Data Bases

When one considers establishing an IRM architecture for the building process, one must recognize that there are two major types of data required over the facility life cycle: general data that are applicable to a class of projects and project-specific data that are developed during the building process by the various participants. These are, of necessity, related, and project data bases must be able to extract information from general data bases and vice versa.

Many of the general data bases already exist in the form of professional handbooks, product catalogs, and computer programs. These data bases may be national, regional, institutional, or discipline-based in scope and application. Examples of data included in general data bases follow in Table 1-1.

The second category of data bases contains data from all phases of the building process for a specific project. This begins at the point when a need for the facility is identified and continues through the life of the facility. A facility's life cycle can be divided into a variety of phases, but for the purposes of this report, the facility life cycle is divided into six phases (see Figure 2-1). These are: (1) planning and programming, (2) design and engineering, (3) specifications and procurement, (4) construction and outfit, (5) building

TABLE 1-1 Examples of Data for General Data Base

1. Regulatory
   - --Building codes and standards (national, regional, and local)
   - --Professional standards (ASHRAE and ACI)
   - --Handicap access
   - --Life safety
   - --Security
   - --Historic preservation
   - --Zoning ordnances
   - --Land use restrictions

2. Institutional standards
   - --Guide specifications
   - --Standard criteria
   - --Standard details

3. Environmental
   - --Climatological
   - --Topographical
   - --Seismic
   - --Demographic and economic
   - --General statistics (transportation and utilities)

4. Behavioral (human)
   - --Physical factors
   - --Ergonomic
   - --Psychological

5. Technical
   - --Design experience
   - --Construction experience
   - --Knowledge
   - --Techniques

6. Construction products
   - --Information on availability
   - --Manufacturers
   - --Technical characteristics
   - --Product performance
   - --Installation procedures

7. Legal
   - --Contracts
   - --Case law
   - --Procurement regulations

TABLE 1-1 Continued

8. Economics
    --Unit costs (all levels)
    --Labor, materials, and equipment costs
    --Productivity data
    --Market conditions
    --General economic conditions and data (interest rates, investment levels, and other financial intelligence indices)
    --Operations and maintenance costs
9. Construction
    --Resources data (current and planned)
    --Activity data (current and planned)

10. Research
    --Construction management and marketing (sources of potential business)

11. Services directory
    --Contractors (primes and subs)
    --Architects and engineers
    --Construction managers
    --Specialized consultants

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maintenance and operation, and (6) user operation. These phases are considered to be more function-related than time-related. They cover all aspects of the project, from "cradle to grave," including acquisition, operation, management and renovation. These phases do not necessarily imply a time scale. Examples of the data included in project data bases, cumulative by phase, follow in Table 1-2.

WHEN TO COLLECT DATA

An integrated approach to the building process implies that the participants will be able to exchange and use information in ways that contribute constructively to the overall process. Data sources required to support this integrated approach are beyond those currently in use. Data input will originate from a wide variety of organizations at different points in this process. Emphasis must be placed on when data are captured and how that timing supports the real-time, interactive, integrated project data-base system. We must decide when is the most cost-effective point to collect data. While data are valuable, they also can be expensive to acquire and record.

TABLE 1-2 Examples of Data for Project Data Base

---

1. Planning and programming phase
   --Functional description
   --Space requirements
   --Site context description
   --Site evaluation criteria
   --Economic feasibility model
   --Special user requirements
   --Codes/regulations/legal constraints
   --Performance requirements
   --Management plan
   --Marketing/selling data
   --Budget limits
   --Management development approach.

2. Design and engineering phase
   --Space allocation
   --Space organization
   --Constructed elements
   --Quantities/costs
   --Equipment
   --Population distribution
   --Expected performance of the design configuration (such as cost and energy use)
   --Options (left to choice of builder)
   --Operations and maintenance
   --Training plan for operations and maintenance
   --Cost of design production
   --Plans and specifications
   --Test specifications
   --Requirements compliance
   --Cost estimates
   --Structural load calculations
   --Energy analysis usage projections

3. Specifications and procurement phase
   --Structure and procedures of procurement process
   --Scheduling
   --Quantities
   --Estimated costs
   --Sources of supply and payment
   --Furnished items
   --Contract documents
   --Shipping

TABLE 1-2 Continued

4. Construction and outfit phase
    --"As-built" information
    --Shop drawings
    --Design refinements (graphic, specifications)
    --Materials bought
    --Equipment bought
    --Actual costs
    --Change orders
    --Construction schedule (daily log of events, people, environment)
    --Productivity
    --Test results
    --Status and forecasts
    --Construction rates

5. Building maintenance and operation phase
    --Expenses and financing
    --Renewal/replacement
    --Servicing/preventive maintenance schedules
    --Repairs (service requests and demands)
    --Redecoration and remodeling
    --Training costs
    --"As-built" drawings
    --Equipment/material listings and specifications
    --Warranty/guarantee information
    --Punch list resolution
    --Operating manuals
    --Energy usage

6. User operation phase
    --Space assignments
    --Space utilization
    --Communications assignments
    --Furnishings and equipment inventory/assignment
    --Functions performed
    --Productivity
    --Remodeling and renovation costs
    --Income/expense model
    --Occupancy costs
    --Layout detail
    --Growth projections
    --Space/function requirements
    --Drawings and specifications
    --Special requirements

Full consideration should be given to collection costs and to minimizing the impact on the work process. Automatic generation of data and the creation of data from the computer-aided design process need to be maximized. Criteria are required to develop timing rules appropriate to the various functions and phases of a project. The criteria must recognize the commonality of how entities will use these data. Entity flow charts are required to provide the structure needed for development of timing rules. We anticipate that data will be both centralized and decentralized. Therefore, full consideration should be given to user locations and whether data are required as soon as they are created. Due to the data sharing, timing must consider the integrity and accuracy of the data shared.

If we wait to collect data until the system is put in use, we allow a period of time to stand between the collection and the first use of the data. This elapsed time can be critical to the process because important information can be lost, the data can be misused or misplaced, or not available when needed. The incentive for waiting to capture data is that you postpone the time when you have to start incurring file maintenance costs. Instead, the data file is written once for the building process, and little updating is required.

Collecting data at the source improves accuracy, and minimizes the chance of data being lost, misused or misplaced. Once the data are recorded, they are available for use by others in the process. However, early record keeping requires file maintenance--perhaps the greatest barrier to early data collection. For a large project, file maintenance is an expensive process. It is, however, less expensive than the time required to collect and verify data at some later point in the process.

The most logical point to collect data is at the source (or when the data are first used). The source generator of the data must be held responsible for updating the data as required. Such single point responsibility will help insure the accuracy and integrity of the data base.

CONCLUSIONS AND RECOMMENDATIONS OF THE WORKING GROUP

Major benefits of an integrated project data base will accrue to the owner. Therefore, development of the data systems will focus on the information needs of the owner. The changes in the building process brought about by an integrated data base will allow the owner to realize the benefits which flow from the use of computer-based systems.

The working group on data capture believes that research projects should be undertaken that analyze the area of data requirements from the programming phase through the occupancy and use phase. In addition, the data flows in the building process should be analyzed to identify data to be captured at each step in the process.

The working group specifically recommends three areas of research. They are:

1 Research should be undertaken to quantify the expected gains of implementing an integrated data-base system in comparison to the dollar and personnel resources necessary to implement such a system.

2. Research should be undertaken to understand the impacts that automation of the design process will have on existing personnel and the resistence that might be encountered by existing personnel.

3. Research should be conducted on the degree of automation that is appropriate and effective for the design process.

Finally, the working group encourages the continued support of university research in all areas of advanced technologies in the building process. University research should serve as the underpinning to the aplications-oriented developments discussed at forums such as this workshop.

2

PROJECT DATA UTILIZATION INTERFACES

The project data utilization interfaces group was asked to start from the premise that, in principle, there is not a series of data bases for a project, but conceptually, one data base. The group was asked to consider the data elements that make up an integrated data base, how they will be used, and by whom. For example, information generated in the programming stage could be valuable to the designer as well as the facility manager (to be used after the project is completed). How should this information be reformatted to be usable? This working group considered these and other interface issues that must be addressed before an integrated project data base can be developed.

OBJECTIVE

This group examined the data transfer and utilization interfaces that occur among the project data and the technical and management processes through the life cycle of a facility. This involved describing how a project is organized, locating where data are developed and used, and examining the data transfer points between the participants. This group considered the question: What will the future building process look like, and how will it most effectively use the project data?

BACKGROUND

The process of creating a facility, from the planning of the project to its actual operation, is organizationally fragmented through divisions of labor and corporate structures (e.g., design, construction, facility management, etc.). It is further fragmented by functional responsibilities such as architectural design, mechanical and electrical engineering, and so on. Data supporting these fragmented organizations and functions must flow through many interfaces if a cohesive, well-developed facility is to emerge. The structure and operation of these interfaces within a data base are major ingredients of effective data communications.

Currently, the orderly flow of data between organizations and from function to function only exists where management has an interest in making the process work. Otherwise, the data flow can best be described as serial. For example, data that are developed and incorporated into the design of the facility may or may not pass through to the construction phase or the facility management phase, even though sharing of data may be critical to the effectiveness of downstream functions. The original data may be lost, transformed, or even recreated throughout the different phases of the building process.

The efficiency of an interface depends on the type of data (such as words, numbers, models, or graphics) and the means of processing the data (such as machine, written, or oral). The integrity of the data as they flow through the interface is a major concern. Considering the permutations that are possible and the requirement for data integrity at the interfaces, it is necessary to either improve the interface efficiency or to reduce the number of interfaces.

In addition to facilitating the flow of data across the interfaces for use in another function, it should also be recognized that if one of the dependent functions changed the data (for example, changing a design decision), then the impact of the change on other functions must also be addressed. This is an issue of data consistency throughout the entire building process. This is essentially a management function that either automatically transfers data or informs the data base of the change. The separate organizations and functions in the current structure of the industry have developed workable interfaces for the traditional media (such as drawings and specifications on paper), but these do not span the entire building process, nor are there any umbrella mechanisms for computerized data.

The following trends support the evolution of a fully-integrated project data base:

- The increasing complexity of facilities (e.g., "smart" buildings) requires substantially more data and analyses. This tends to increase the number of organizational, functional, and informational interfaces, and adds to the difficulty of storing and manipulating data.
- Developments in information technology will make it possible to handle more effectively the data and information required for decision making and documentation by all participants in the building process.
- There is a continuing need for timely, accurate and low-cost information.

ASSUMPTIONS

This group made the following assumptions:

- Computer technology (software and hardware), telecommunications, and other electronic technologies will be involved in processing of the data required by the facility development team including textual, graphic, numeric, and symbolic data.
- The cost of information technology will continue to fall in real terms.

- Machine-to-machine interfaces will be possible and will be able to occur independently of the manufacturer.
- External data bases will be available in machine-readable form.*
- The technology for integrated data bases, including how to make data consistent, will be available.

DESCRIPTION OF AN INTEGRATED DATA BASE

Concept

An integrated project data base, such as that depicted in Figure 2-1, formalizes the interfaces between the various project development functions. Such a data base contains a conceptual model of the project

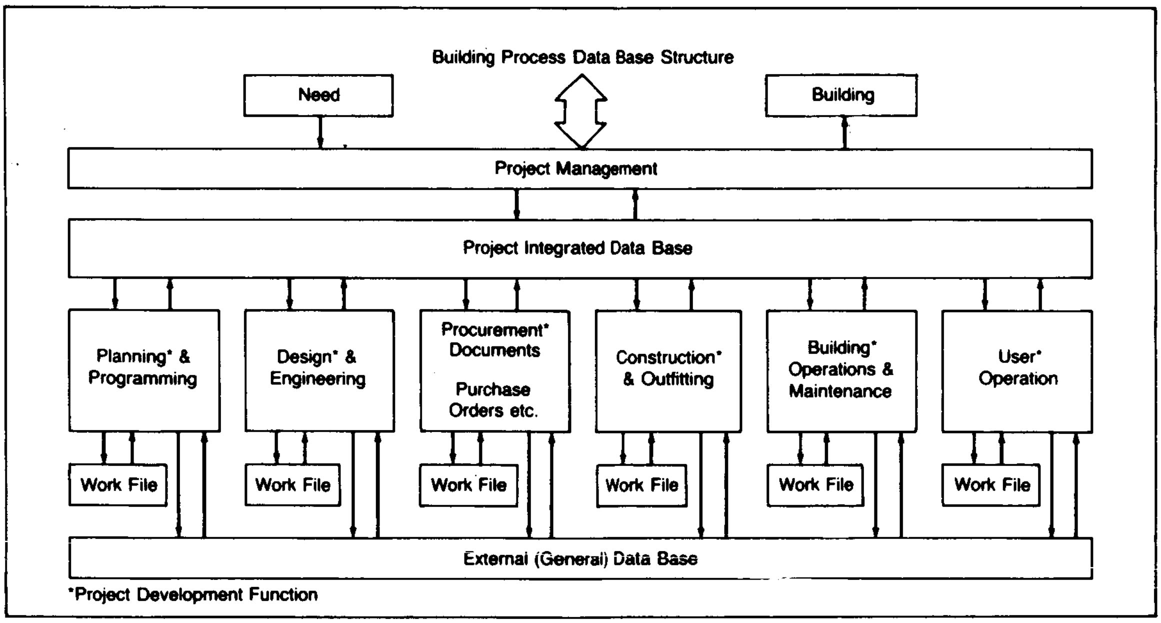

FIGURE 2-1 Integrated project data base.

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*External data bases contain general information relevant to many projects or organizations. They are outside of, or external to, the project data base which includes specific data generated for an individual project. External data bases may include regulations, codes, design standards, engineering practices, and generally accepted knowledge applicable on a national, regional, or institution-wide basis.

that allows the various project development functions to extract required information in a form that is particular to a function as well as to accept information from other functions in a standardized form. The means of accomplishing this is through interface modules that reformat the information. These interface modules contain the knowledge about what form each transfer requires. For example, one element of the interface to the construction function can take components of the mechanical system from the data base and subdivide items such as pipe runs into spool pieces, each with a geometry and a unique part number. After these parts have been installed, the construction system reports back to the data base that this aspect of the mechanical system has been completed and is scheduled for testing at a particular date. The project development function views the data base in different ways. Table 2-1 outlines some of these views.

TABLE 2-1 Data-Base Considerations from Viewpoint of Project Development

Planning and Programm
1. Performance
2. Constraints
3. Spaces, people, functions, relationships
4. Costs/budgets

Design and Engineering
1. Spatial allocation
2. Formal, aesthetic considerations
3. Construction elements
4. Environmental control
5. Operations
6. Cost

Procurement
1. Contracts
2. Drawings and specifications
3. Bidding processes
4. Cost

Construction
1. Construction requirements
2. Purchasing
3. Testing
4. Cost

Operation and maintenance
1. Performance
2. Maintenance procedures
3. Inventory tracking

User operation
1. Staffing and scheduling
2. Space allocation and use
3. Performance

In order to accomplish the desired kind of interaction with the project functions, the content of the data base must be organized in a standard way. This organization need not be uniform across all projects in all designs, but it must share common ideas and concepts on which there is agreement.

DATA INTERFACE ISSUES

A data interface exists at every boundary between organizations, firms, disciplines, and programs that have developed data structures independently. An idealized data base concept would require the elimination of these interfaces. However, the structure of the construction industry--organizationally fragmented--is such that they cannot be eliminated. Each organization and discipline has its own methods and terminology. A group of such organizations comes together to execute a project for a client. Each project team may be unique--never having worked together before and possibly never working together again. This group communicates by means of various documents and information transfers (drawings, specifications, etc.), that have been more or less standardized over the years. Even so, many misinterpretations and misunderstandings occur.

Even within a single discipline, data interfaces occur because different computer hardware and software systems are used for similar functions. For example, many different programs exist for finite element analysis, structural analysis, piping analysis, etc., and each organization performing these functions may select a different program for reasons of its own. Each program requires similar types of input data, but in different formats. Software developers writing interactive graphics programs, for example, must either limit their market by providing communications with only one analysis program or must write separate communications programs.

Similarly, computer-aided design (CAD) systems, although dealing with the same basic entities (lines, arcs, etc.), represent these entities internally in different ways, so that different CAD systems cannot communicate with each other. One answer to this interface problem has been the development of neutral files. A neutral file is an intermediate data representation which does not necessarily reflect the internal storage representation of any specific hardware or software. Instead of writing translators to and from every other software product with which they wish to communicate, software developers need only write translators to and from their system to the neutral format. The Initial Graphics Exchange Specification (IGES) for communication between CAD systems is one existing example of this approach.

Interfaces in the Integrated Project Data Base

As illustrated in Figure 2-1, the integrated project data base serves as a centralized repository of information through which all functions communicate. The integrated data base serves as the primary interface between all aspects of the project. The internal structure of this data base serves as a major vehicle for communication.

Interfaces to and from the data base and the external world need to be addressed in order to clarify their role. While it is inappropriate here to specify formats and technologies, it is useful to outline some of the primary functions and problems at the interfaces.

Role of an Interface

Essentially, all interfaces are concerned with the transfer of data. All transfers can be classified broadly as input functions or output functions. There are, however, more specific operations within these broad categories in the model proposed.

Input Input to the integrated data base comes from a variety of sources--primarily, batch input from the external data base--but also the direct input of discrete items. In general, input can be classified as follows:

1. Discrete input of both structured and unstructured data, e.g., initialization of the data base with project identifier (name, number) and description of project.
2. Bulk transfer of data from the external data base, e.g., setting up of project libraries of standard details and approved equipment.
3. Updating and replacing of existing data, item by item, e.g., minor revisions of equipment specifications.
4. Compaction and replacement of a section of the data base.
5. Supplementing and expansion of existing data, e.g., extending the description of particular equipment with historical data.

Output There are a variety of roles for the data output from the integrated data base. Some of these are:

1. Discrete output by direct querying of the data base, e.g., identifying the manufacturer of a known part.
2. Bulk extraction of data, often to another data base, e.g., down loading selections and projections of the data base. This often requires output in specific record formats.
3. Reporting and tabulation of data base contents, e.g., bill of materials.
4. Extraction of data and reprocessing before use by the recipient, e.g., reporting of geometric data as areas instead of nodes and vertices.

Interfaces are required, therefore, not only to transfer discrete data elements, but to reformat one data structure to another. There is an important role for the interface in the reinterpretation of the data, including the extraction of implicit information (e.g., the derivation of data not explicitly stored in the integrated data base such as the areas of closed polygons).

Consistency

One of the most important qualities the project data base should have is the ability to maintain consistency among the data stored. While a central data base that all participants share solves many of the uncertainty problems caused by independent data bases, changes entered in one subsystem can have an impact on many other subsystems. The data base should store relationships between data items and take the correct action when things change. To accomplish this automatically is very difficult with current data base structures. An automated system should send messages to the participants about changes that may affect their work. Project management techniques that study the impact of changes will be required to maintain those aspects of consistency that are not automatically accomplished.

While the intention is to maximize the value of information transferred by making the data as complete and fully contained as possible, it is also a practical issue that the volume of data be minimized. The interface needs to be as rich as possible while maintaining consistency.

There are a number of ways of achieving this richness. The most common technique available is to employ representational codes which, in their structure, are embodied with value. For example, we can establish codes for geometric shapes in which we use numeric symbols to represent standard shapes. This technique can be extended to more complex objects by the use of standard master libraries established as general standards. Such libraries can be devised as uniform classification systems or can be allowed to evolve in the marketplace. The latter can be similar to that employed in the establishment of bar codes in the grocery industry.

IMPLEMENTATION ISSUES

How an integrated project data base can be supported across differing computer environments and how differing project organizations can be accommodated within the same data base structure are the major implementation issues.

Implementation in the Federal Sector

Implementation of an integrated project data base in the federal sector should cause minimal disruption if undertaken in an evolutionary manner. Most agencies already have computer-based systems for some building-related functions, although the practice is uneven and piecemeal on an agency-by-agency basis. This fragmented development is due, in part, to the lack of a single organization responsible for all aspects of a project. There is no "czar" in a position to influence the process at organizational and functional interfaces. This situation will most likely continue to exist without changes in responsibilities and construction procurement methods.

Project management in the federal sector generally is not vested in one individual or organization throughout the life of the project. However, the organization responsible for the design and construction can make the proposed system work, provided the agency requires that the necessary procedures be followed during the programming and planning stage. The design/construction organization must be responsive to the needs of those responsible for operations and maintenance, and to the needs of the users.

It must be recognized that agencies have a significant investment in existing hardware and software. Procedures and policies implementing the integrated project data base must be flexible enough to allow interfaces within these existing systems. It should also be recognized that some existing hardware may be too limited in its ability to work with an integrated data base.

Implementation in the Private Sector

Because of the fragmentary nature of the construction industry, it is unlikely that a single service firm will be able to implement a complete integrated project data base independently.

Large design/construction firms will continue to move toward internal project data bases, particularly on large projects. The economic advantages of increased efficiency may make such integrated firms more competitive with respect to project teams of smaller, specialist firms. However, even large design/construction firms will find it difficult to implement and integrate project data base alone, and will, therefore, have to maintain data bases that are open to a variety of suppliers and clients.

The economic benefits of improved data bases will accrue primarily to the owners. Some of the economic advantages are:

- Increased accuracy of estimates by automatic quantity development;
- Reduced construction interferences through automatic interference detection or prevention;
- More rapid processing of design changes;
- Reduction of errors due to manual data transcription;
- Reduction of design errors due to use of obsolete information;
- Better quality drawings;
- Reduction of drawing revisions by use of pre-release design review by all involved parties;
- Improved designs due to development of multi-disciplinary design tools and methods;

- Reduced construction costs due to better construction planning and improved transmission of design information to construction (interactive computer graphics displays); and
- Reduction in facility operation and maintenance costs due to improved availability of as-built data and design criteria.

Data-Base Ownership

The issue of data-base ownership must be resolved in order for an integrated project data base to be successful. Clear responsibility for ownership, and the associated responsibility for maintaining data integrity, must be established. The problem facing data-base developers is not the elimination of data-base ownership at the organizational level, but how to exploit the ownership function as a means of data management.

Data bases have no independent life, but exist only as products of some function. If a function is not computerized, then a computerized data base dependent on that process can be maintained only by continuous management attention.

Trends

Progress in computer technology, increased user experience with that technology, and improved economics are trends that contribute to advancing the concept of an integrated project data base. Progress in computer technology includes improved microprocessors, workstations, peripheral equipment (digitizers, plotters, tablets, etc.), and distributed networks or telecommunications. Increased user experience includes a growing acceptance of (and investment in) microcomputers and workstations, and the ability to use this capability to support group objectives, rather than individual efforts. Favorable economics results from the need to extend finite budgets through increased productivity and efficiency, while preserving the unique contributions of the various technical experts involved. Economics also includes the decreasing cost of computer hardware and the range of capabilities that are now available. The use of computer-aided methods (for mapping, drafting, design, and manufacturing) is becoming more commonplace and is sometimes required if firms are to compete successfully for public sector contracts.

Another factor to consider is the life of computer systems. Regardless of the pace of evolving technology, system upgrades and/or replacements are strongly influenced by tax laws (depreciation schedules and investment tax credits) for private industry.

CONCLUSIONS

This working group concludes that an integrated project data base will be an effective mechanism for bridging the interfaces that exist throughout the life cycle of a building project. Many interfaces exist between the participants in the building process, between individual project functions, and between the data that are collected and analyzed for the various project functions. This multiplicity of interfaces makes the building process complex and exceedingly difficult to manage. An integrated project data base will be a valuable tool for bridging these interfaces and for creating a means of communication between people, functions, and data.

Opportunities for easing the interface problem are significant through the development and use of an integrated project data base. Because of its potential for stimulating better, more informed decison making and more efficient management, a strong economic incentive exists to move toward the creation of integrated project data bases. Its development should help to pull the separate pieces of the building process together, resulting in more cost-effective buildings.

As is true in other applications of advanced technology, there are potential barriers to realizing the full benefits of integrated project data bases. Careful planning and the involvement of management are necessary to establish an integration strategy, including the rules, guidelines, and criteria that will assure consistency in the data base. Proper training and preparation of staff are essential to assure that the rules are followed.

Managers may find that they will need new organizations or new organizational relationships when implementing the integrated project data base. These new relationships should result in improved communications between people, processes, and data, as well as fewer interface problems.

BENEFITS

The integrated project data base has at least four tangible benefits: (1) improved communications across the interfaces, (2) improved project management, (3) more consistent data, (4) and better analysis and design.

Improved Communications

By providing a common means for communicating about the project, the integrated project data base will help to make the many interfaces invisible and will provide a means for solving the interface problem. Although some of the data used in the building process are specific to a particular function, other data could be useful throughout a project's life cycle. The integrated project data base will be a tool for the communication of these common data across the interfaces of the various professions and creators of the data. It will act as a surrogate integrator of people, processes, and data.

Another aspect of the integrated project data base is its potential for facilitating change. Many changes occur in a project after design.

Currently, one of the most difficult interfaces to bridge is that between what was planned for a project and what actually exists as a result of the many changes that have been made. It is important to pass the information related to change to project managers and to other participants in the building process who need to know about changes in order to perform their jobs effectively. The integrated data base will be a way to accomplish this.

Improved Project Management

A second major benefit is improved project management. Because no one organization has control of a building project from beginning to end, no one organization can capture the data that are needed throughout the process. The creation of an integrated project data base will allow a project manager to improve significantly control over a project and increase the project manager's ability to monitor and channel change.

Data Consistency

A third benefit is more consistent, reliable data through all phases of the building process. The use of advanced computer technology to create and maintain the integrated project data base will stimulate discipline and precision in the data capture and representation processes. Certain formalisms and guidelines will be required to assure that data stemming from the various segments of the building process are consistent. This quality is essential to the effective operation and use of an integrated project data base and to the easing of the interface problems.

Analysis and Design

Better processes for analysis and design are additional benefits flowing from the creation of the integrated project data base. By creating a repository of the essential decisions that have been made about a project and a record of changes made, the integrated project data base will allow the various participants in the building process to respond to change and to use the data generated and collected by other participants. As a result, the interface between past experience and future activities will be bridged.

RECOMMENDATIONS

The two workshops on Advanced Technology for Building Design and Engineering have produced definitions of an integrated project data base and have identified issues in terms of barriers and incentives, or advantages and disadvantages. This workshop has produced a graphic depiction of an integrated project data base in terms of its relationship to project management and to the multitude of functions that both extract from and contribute to the data base. The next step is to execute the generic model for a defined project so that the various interfaces can be defined and examined. If a goal of the integrated project data base is to preserve only common and "useful" data, such an exercise would identify such data.

The establishment and use of an integrated project data base is not a linear process--starting at one point and progressing to the end--but rather an iterative process without a fixed start or end point. Hence, this working group suggests that at least two separate groups be involved in the establishment of the integrated project data base. Each group would start at a different point in the process. If the data are unique, then each group should arrive at approximately the same set of data elements.

Several federal government agencies are establishing data bases to support their project needs. The National Research Council should assign representatives of the Building Research Board to "watch" and document this experience so that it may be available to assist others facing similar tasks.

A potential product of Building Research Board's efforts could be a guidebook for use in establishing an integrated project data base. Recent efforts by the American Public Works Association have resulted in the publication of guidance materials for computer-aided mapping. This guidance contains documentation of actual experience (case histories) as well as rules-of-thumb derived from that experience. Singular or cooperative efforts to assist users with integrated data bases is offered for consideration.

3

DATA-BASE REQUIREMENTS FOR ANALYTICAL METHODS IN EARLY DESIGN DECISIONS AND POST-CONSTRUCTION FEEDBACK

This group originally was assigned the topic of linking a data base to graphics representation. The group reasoned that graphics representations are an input/output function rather than a data-base function. It decided that the area needing attention was data-base requirements for analytical methods at the programming, design, and post-construction phases.

INTRODUCTION

Current technologies already use integrated data-base management systems to manage geometric models and their attributes, to select output data to generate drawings and specifications, and to select data required as input to analysis programs. From design definition through design analysis and construction, such systems are now being effectively used and refined. Preliminary design aids and post-construction feedback, however, have not yet been successfully implemented in current computer media.

It may be that these aspects of the building process have been less tractable for computer application because they are less compatible with present computer media. Current computer media, with their emphasis on digital methods, may not be adaptable to the generality of human image manipulation in preliminary design. Images manipulated by designers in preliminary design processes, sometimes augmented by designers making sketches with a 6B pencil, are not of the discrete data images now handled so effectively by computers. Therefore, new kinds of computer media, adaptable to preliminary design image, may be needed to accommodate the early stages of design processes and the feedback from post-occupancy analyses that should inform those processes.

This group's discussion examined ways to improve the quality of building by maintaining the intent and philosophy of the building throughout the life cycle of the facility. This was discussed within the context of an integrated data base for a building project.

DISCUSSION

Data Flow in the Building Process

Data should flow in an integrated progression from the point of conception of a facility through its occupancy. As the design progresses through the process, the spectrum of design choices narrows, and the level of detail increases.

Considerable data and information are encompassed in the building process. The intent of a building project originates in the objective statements that are embellished and refined until the concluding step of use and occupancy. Integration of this information into a data base is essential for comparison of the actual design against the originally established intent throughout the stages of the building process.

This capturing of objective information has been overlooked in past attempts at designing integrated data bases. Not only must an integrated data base be structured to allow for verification that the original intents are met, it must be structured so the results of analysis at each step are available for input to the next step. Each step expands on the level of detail set by the previous step in the process. This progression allows for a structured methodology for making and documenting decisions along the way. All previous information and decisions are then available at any future point. They are available to verify or provide warnings for future design decisions or changes.

INTEGRATED DATA BASE

Figure 2-1, developed by the interface working group, is based on the generally understood sequence of operations in the building process. Special emphasis is placed at the beginning stage of planning and programming that defines the reasons why a building is needed. At the end, we place an emphasis on the feedback that can be obtained from the people who use and occupy the building. This group currently has the least input in developing design requirements for buildings. The diagram attempts to show that there has to be an overall management control from the beginning to the end. One of the tools for this can be an integrated project data base. For example, the integrated data base will provide the means for project objectives, or philosophy (that explain why a building is being built), to be kept in focus throughout the building process.

The spectrum of choices narrows and the level of detail broadens as the project approaches the construction stage. If a data base is well organized, it will allow knowledge of requirements and intents to be pushed forward into the stages of design and procurement. This allows, in turn, the testing of more alternatives, allows them to be more consistent, and allows the alternatives to be tested against the objectives. The architectural quality should be improved as a result.

Integrated general and project specific data bases provide the information to begin constructing a computer model of a project. Other computer analysis tools help you rapidly test alternatives and refine this model. These tools will be evaluating everything from structural integrity to human comfort. The analysis tools and computer model will help you during the building decision-making process to improve on the original concept. Each decision in this iterative process will add information to your integrated data base and thus strengthen the whole process.

The use of such tools should provide a considerable saving in time in the design stage and, as a result, allow more design effort to be expended for the same budget. In each stage of the process, there should also be a way of going back to test the new results against the previous model to see if progress (in terms of quality) is being made. This means trusting the integrity and consistency of data of the earlier models (e.g., the volume determined in early designs is reliable for later evaluation). There is a critical need for improved tools and models to support decision making during the building process, especially for master planning, architectural programming, conceptual design, and schematic design. These tools and models will draw their information from the integrated project data base. Therefore, their information needs will be a prime determinant of data-base contents.

NEED FOR ANALYTIC TOOLS

Tools and models are needed at the early design stages because of the high impact of early design decisions on building quality and costs. The further the building process progresses, the less we can affect quality and costs. Quality is a function of costs and costs a function of quality, so that the trade-offs are important to know. Most of the existing computer-aided design tools and most of the expertise in the development of data bases have tended to aid in the more detailed design stages (not necessarily the working drawings stage, but certainly closer to the concept stage than the pre-concept stage). This has meant an emphasis on design tools of value for the design of items once they have been dimensioned.

The integrated project data base should support all stages of the building process. It may be used to record program and early design proposals and to provide input to and receive output from broad-brush analysis models. This allows designers to test their ideas, quickly explore many alternatives, and make major design decisions. By incorporating knowledge and experience (based on feedback) into such systems, designers are given the opportunity to exploit the experiences of others.

The data requirements must be minimal at the early stages of planning and design analysis. Otherwise, the designer is placed in the position of developing an enormous data set and finding that this precludes any further efforts to change the design. The data base must allow progressive design definition and refinement. Both data entry and design analysis must be largely interactive.

The key decisions and reasons for them (including intent and philosophy) may be saved for the information of future building owners, designers, and facilities managers so that the integrated project data base is used to carry forward essential information about the building. The analysis tools and integrated project data base may continue to be used to test proposed changes to the existing building. Design concepts and intent need to be recorded in order to provide a framework to future feedback. Feedback is of no value unless it is in a form that allows comparison with what was intended.

The use of a single, computerized, and consistent data base for a facility with associated tools (for all building stages) may allow for a reduction in size of the design team. This, in turn, could lead to a smaller, more integrated design team that is better able to coordinate design decisions and uphold the building intent.

BARRIERS AND INCENTIVES

Barriers

The application of computer technology to the building process has focused historically on functions that are well understood and quantifiable in logical terms. Examples include automation of the drafting process and construction management support. The front end of the building process has not benefitted substantially from automation. Automation support has occurred where improved cost, performance, and efficiency are demonstrably achievable.

We believe automation will benefit the front end of the building process. Barriers exist, however, particularly with respect to the use of data bases in the early design stages. While none of the barriers are "show-stoppers," they are real and significant . Some barriers are:

1. Functional requirements have not been specified for the data base. While this workshop is a start, we believe the front-end process has not been adequately described, nor has the need for automated support been clearly established. The process sequence and the roles of participants are not standardized.

2. No sponsor with incentive and sufficient developmental resources has emerged. The data-base ownership issue remains unresolved. These are a result of given economics such as:

- Developments are perceived as high-risk undertakings with a questionable return on investment;
- The cost/performance improvements are extremely difficult to predict and quantify;
- Industry practices, such as the existing fee structures, do not provide incentives; and
- The potential beneficiaries have not established a market.

3. While specialized analytical tools exist, they often are not readily accessible when and where needed.

4. The tools and models must serve, rather than drive, the process; they must be capable of evolving and providing flexibility rather than imposing barriers.

5. Tools and models can be perceived as a threat to the status quo and any implied hierarchy of participants.

Incentives

In general, the incentives are:

1. The building owner has the greatest incentive to see the sort of improvements envisioned here put in place. Since operation costs are such a large factor in the life cycle of a building, owners should have a major influence on implementing these developments.

2. In the long run, participants have an incentive that comes from improved decision making and improved cost controls.

RECOMMENDATIONS

1. Improved analytical tools are needed to support decision making in the early programming, conceptual design and schematic design stages. These tools must be suited to the information available at the design stage and provide reliable and timely results to contribute to teamwork in the building process.

2. Research and diagnostics on existing building performance, and on the relation between design results and the effectiveness of construction, operation and maintenance practices, are required to verify analytical tools and to create the required generic data. These research efforts must generate the needed families of analytical tools.

3. Public, neutral, interface data descriptions (information interface standards) are needed to allow algorithms, software and hardware for project data bases, generic data bases, and analytical tools to be developed independently but applied integrally.

4. Projects for important building types should be studied systematically (from earliest design phases through construction and occupancy) to document needs for data and analytical tools, the data management and analytical techniques currently used, and their effectiveness. A starting point and an evolutionary process for integrated project data bases and decision support tools in the early design phases need to be established. An environment conducive to the development of verified, rational analytical tools must be established.

5. Efforts should be made by major owner-users, professional and trade associations, and research institutions to sponsor, conduct, and apply research for improved analytical tools for decision making in early design phases.

PART II

PRESENTATIONS

DATA-BASE REQUIREMENTS AT THE PLANNING AND PROGRAMMING STAGE

Fred Kitchens
Assistant Chief, Engineering Division, Savannah District
U.S. Army Corps of Engineers, Savannah, Georgia

This presentation deals with the planning and programming stage of a building as it begins and progresses through its usable life. The Savannah District of the Corps of Engineers is involved in the area of planning and programming by assisting the installations we support. There are a number of data elements that are generated in this stage of a facility's life. I will present what some of those data elements are. The categories of data elements relate to functional requirements, siting information, utilities to support the facility, design criteria that influence the scope and funding, and, finally, cost.

THE U.S. ARMY CORPS OF ENGINEERS

In order to understand our activities, I will briefly describe the Corps of Engineers organization and how we relate to other elements of the Army. The Corps consists of 14 divisions and 41 districts located throughout the world. The Savannah District, with which I am associated, is located organizationally within the South Atlantic Division. We are responsible for supporting Army installations in Georgia, North Carolina and South Carolina, and Air Force bases in Georgia and North Carolina (Figure 4-1). Georgia has the largest number of Army and Air Force installations. Fort Jackson, which I will talk about in more detail as we proceed, is in South Carolina, northeast of Columbia.

We are involved in all aspects of a project from the beginning to the end. While we are not directly responsible for programming and planning, we do that work upon request in support of the Army customers we serve. Our primary function is to provide engineering, design, and construction support for Army and Air Force facilities.

The Military Planning Section of the Savannah District Engineering Division is the interface for planning and programming support for installations that request these services. Anyone involved with the federal government recognizes that until Congress appropriates the money for a project, there is no project as far as construction is concerned. However, the planning for that project started many years before.

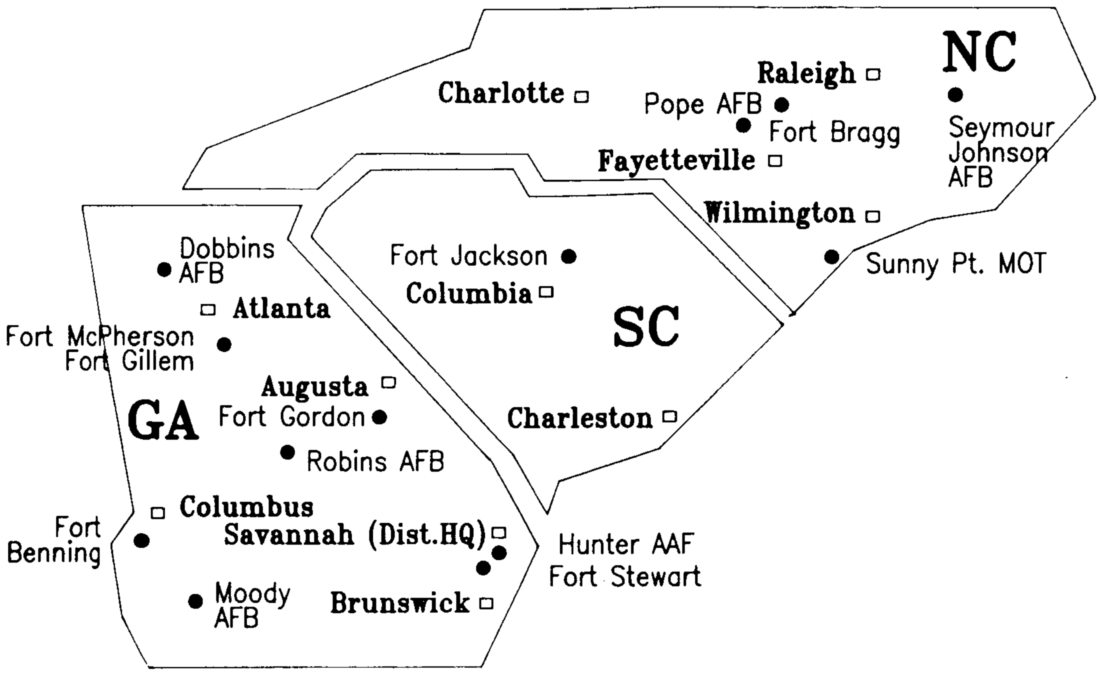

FIGURE 4-1 Savannah District military boundary (construction and real estate).

At any one time there are four major overlapping programs as shown in Figure 4-2. They are the MCA (Military Construction-Army), the FYDP (Five Year Defense Plan), the POM (Program Objective Memorandum), and the MACOM FYP (Major Command Five Year Plan). A project is generally first identified as part of the MACOM FYP and progresses through the four major programs over an eight-year period. The first four years are generally the planning and programming years. The fifth year, the guidance year (GY), is part of the MCA Program; the final programming documents are completed and the project enters the design stage of development.

Many of the data elements generated during those first five years of a project are needed in the design stage spanning the guidance year (GY), design year (DY), and budget year (BY) of the MCA Program. In addition, many more data elements will be initiated during these years as a result of technical and management needs.

Time Now – FY 84

FY	MCA Years		FYDP Years		POM Years		MACOM FYP Years
84	PY						
85	BY	–	No.1				
86	DY	–	No.2	–	No.1		
87	GY	–	No.3	–	No.2	–	No.1
88		–	No.4	–	No.3	–	No.2
89		–	No.5	–	No.4	–	No.3
90			85–89	–	No.5	–	No.4
91					86–90	–	No.5
							87–91

FIGURE 4-2 Progression of an Army project.

The DD Form 1391 is the document used to identify a project and state in general terms the facility requirements. Items 1 through 10 of the 1391 (Figure 4-3) are standard on the first page of the document and represent the project on its initial submittal for consideration. In the guidance year the project is released, eighteen paragraphs of specific data are added to complete the 1391 with further justification for the project. These paragraphs contribute additional data elements that will be needed in various stages of the project.

AR 415–15 | 1 December 1983

1. COMPONENT	FY 1985 MILITARY CONSTRUCTION PROJECT DATA	2. DATE
ARMY		03 DEC 80

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
Fort Sill Oklahoma	Trainee Barracks

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST ($000)
	721 31	265000	24,553

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY				17,791
ENL Bks w/Mess	SF	171,610	56.40	(9,679)
Seismic Zone 1 (Add 1.0%)				(97)
Enl Pers Dine	SF	16,700	147.21	(2,458)
Adm & Sup Bldg	SF	13,500	75.57	(1,020)
Bn Admin & Clrm	SF	18,945	73.00	(1,383)
Covered Training Area	SF	[illegible]4,000	[illegible].81	(2,150)
Addn to Central Energy Plant	SF	2,800	[illegible]8.64	(1,004)
SUPPORTING FACILITY				4,479
Electrical	LS	--	--	(389)
Water Lines	LS	--	--	(134)
Total from Continuation page				(3,956)
SUBTOTAL				22,270
CONTINGENCY PERCENT (5.00%)				1,114
TOTAL CONTRACT COST				23,384
SUPERVISION INSP & OHEAD (5.00%)				1,169
TOTAL REQUEST				24,553
INSTALLED EQUIPMENT-OTHER APPROP				(0)

SAMPLE

10. DESCRIPTION OF PROPOSED CONSTRUCTION

The primary facility is permanent reinforced concrete and masonry construction. The work is new construction, site adapted from two similar buildings on the installation. The structure is noncombustible housing barracks for 1100 trainees and 36 enlisted personnel. In addition, the complex will include classrooms; administration and storage; dining facility; battalion headquarters; covered training areas and an addition to the central energy plant. The central energy plant will be coal fired providing high temperature hot water heating systems and 480 tons chilled water air conditioning. The project will include required utilities services, communications, fire protection and alarm systems, paving, walks, curbs, gutters, storm drainage and site improvements. Not sited in a flood plain. Demolition of existing buildings is not required for site clearance. Accessibility for the handicapped will be provided.

11. REQUIREMENT: 8,383PN ADEQUATE: 2,504PN SUBSTD: 6,893PN

PROJECT :
Construction of a 1100 trainee barracks with dining, admin and classroom facilities at Fort Sill, Oklahoma.

DD FORM 1 DEC 76 1391 PREVIOUS EDITIONS MAY BE USED INTERNALLY UNTIL EXHAUSTED PAGE NO

FOR OFFICIAL USE ONLY
(WHEN DATA IS ENTERED)

7-10

FIGURE 4-3 The DD 1391 form.

INSTALLATION MASTER PLAN

In order for a project to be accepted as part of the program, it must be on the approved installation master plan or an accepted site development plan. Master planning is involved and divided into five major phases.

Phase I is an accounting of the existing facilities: What is on the site, how many buildings are there, what are they used for, where are they located? Both graphical and tabular information are necessary. Those maps have been traditionally prepared at a scale of 1"=400' and have been used primarily as a master plan document. They depicted what was there and no more.

Phase II is an analysis of future requirements, and overlays Phase I, the basic information maps. It superimposes new facilities that are required. Every project in the MACOM FYP should be reflected in the Phase II document.

Phase III shows the utilities required and is another overlay of the basic information and future requirements. It shows not only the graphic representation of those utilities, but also includes studies and analyses to determine what is necessary to support a new project.

Phase IV is the expansion capability plan for the installation. It identifies what can be placed on the installation and answers the question of how many people could be accommodated under a peacetime situation?

A mobilization master plan consists of the physical composition of the installation and a plan for an orderly comprehensive development to support full mobilization with the capacity for total mobilization.

AUTOMATED INSTALLATION GRAPHICS SYSTEM

Since the late 1970s there has been a great deal of interest in automating the master planning process. As a result of previous work by the Savannah District, we were asked by TRADOC (Training and Doctrine Command) to evaluate the potential for an Automated Installation Graphics System for Fort Jackson, South Carolina. A contract was awarded to Mid-States Engineering in 1982 to create the interactive data base and to develop the system for managing and using the data.

I understand that one of the reasons Fort Jackson was chosen is because it is the smallest installation in TRADOC that has all of the prerequisites necessary for a complete test of the system. Even so, a large data base resulted--approximately 500,000 blocks of data. The basic data in the cantonment area were collected at a scale of 1"=100' and the remainder were at a scale of 1"=400'. Data were collected using aerial photography, stereo digitization, and existing documents such as basic information maps and as-built drawings.

The results provided graphic data and non-graphic attribute data for access by users of computer-aided design and drafting systems. The system also has an interactive graphic design system and a data management and retrieval system. The system has provided the master planner with the tools necessary for master planning and for use in programming of facilities.

Let's go back to the programming process. The functional data necessary to prepare the Form 1391 are obtained from the user and documented in the PDB-I (Project Development Brochures). While all of the information that is contained in the PDB-I is not used in the Form

1391, it is essential input to the design stage of the project and, therefore, must be retained. After review and approval of the PDB-I, the front page (items 1-10) of the Form 1391 is submitted through the MACOM to the Department of the Army. If considered a viable project, the full Form 1391 is prepared and submitted for approval. Most of the information necessary for the Form 1391 is required during subsequent stages of the project development.

The Form 1391 is generally prepared using the 1391 Processor which originated as a subsystem of the Computer-Aided Engineering and Architectural Design System (CAEADS) and is now a subsystem of the Military Construction Programming Administration and Execution System (PAX). Use of the 1391 Processor makes the information for each project available through automated means to all participants in the project development process. As part of PAX it feeds the Program and Project Management Systems and, with proper interface with CAEADS, could transfer data to the design stage. Using the 1391 Processor makes the information universally useful as well as enhances the programming process. The information is readily available to all offices and participants in the approval process; it can be recycled quickly as many times as necesary at each step in the process.

DATA ELEMENT CATEGORIES

The major catagories of data elements generated in the programming and planning stage are useful in both the programming document as well as input to the design stage. As now defined, we see the possibility of having all that data available through automation. For example, functional requirements identified in the PDB can be automated; master planning support systems, as developed for Fort Jackson, can provide information necessary for site development and utility support; the PAX System can provide information from the 1391 Processor. The cost data for programming support are under development. We are approaching the full capability to provide an automated means of providing data generated in the programming and planning stage to subsequent stages of project development.

The source of information generated in the planning and programming stage is well defined. However, the usefulness of the data in subsequent stages of the project varies. Most of the data are useful in the design stage and, in varying degrees, in the construction and operations stages. Time, money, manpower, and other resources can be more efficiently used and more responsive facilities can be provided to the user and the owner if we provide assurance that the data, once generated, are preserved and made available to subsequent participants in the building process.

5

DATA-BASE REQUIREMENTS AT THE ENGINEERING STAGE

Richard N. Wright
Director, Center for Building Technology
National Bureau of Standards, Gaithersburg, Maryland

This session deals with data requirements at the engineering stage. We are looking at an environment in which there is an integrated project information system or data base. This is represented in Figure 5-1. Throughout the whole history of the building project, from programming through occupancy, a variety of participants can access the information system to get the input data that they need to do their own data processing, carry out their analyses, and make their decisions. They then can put back into the system the output information that is needed to inform other participants of their decisions.

There are a couple of things I want to mention to reveal my own thinking. One of them is that as we work through the whole building process, we are striving to produce a quality product, a building that has attributes such as usefulness, safety, and economy. A building should support its intended purpose. The people who are in it or are affected by it should not be subjected to undue hazards to life, limb and property. The building should pay back to the investors and the public a profit on the resources that went into it.

Another thought that I am testing this week is that if we are going to achieve effective, integrated computer-aided design, we need an open construction process. It should be open in the sense that it is possible for a variety of people to compete fairly for the opportunity to participate as a manufacturer, as a designer, as a developer, or as a subcontractor to interact with the other participants and the project information system and make an effective contribution. This openness, as well as extending to people, will extend to the information. We have security and privacy problems, but people must be able to get the information that they need to carry out their role effectively. The information systems need to be open to the variety of hardware and software that the various participants may possess.

A number of you may have seen an article that Ken Reinschmidt wrote for Engineering News Record last fall.* Ken pointed out very

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*K. L. Reinschmidt and D. L. Lersch, "Communicating Computers a Must," Engineering New Record, September 29, 1983, p. 62.

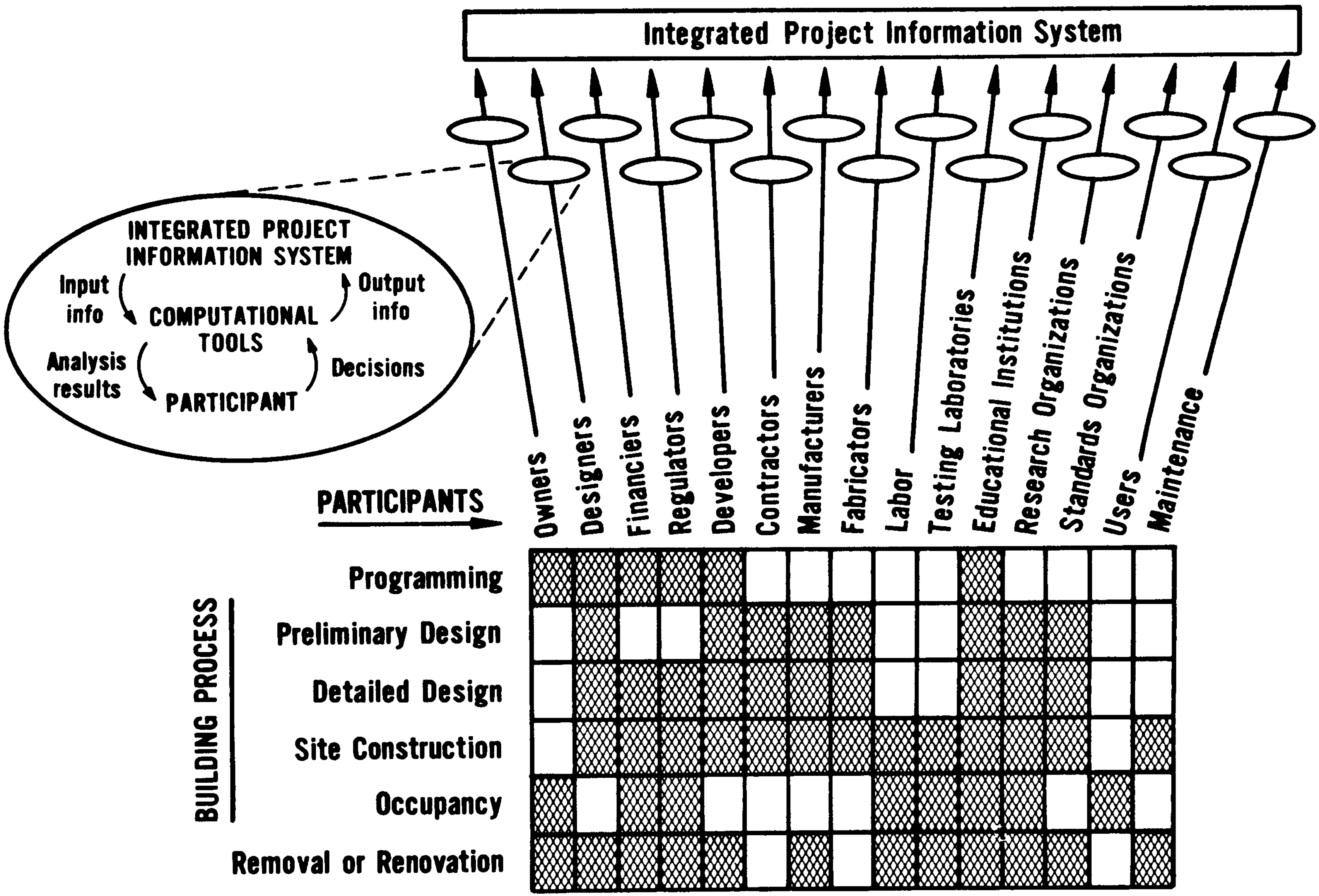

FIGURE 5-1 Integrated project information system.

forcefully and succinctly the problems associated with the building community's composition of small businesses and the formation of a new team with each building project. Each participant in the process is working on a variety of projects with a variety of different other participants. Like a carpenter with a kit of tools, each participant has hardware and software to support his or her other decisions. He or she needs a process that is open and interactive to exchange information with the other participants.

Another advantage of this openness is that it will support innovation and improved technologies. Openness has a great deal of value in terms of the ability to support effective innovation in a free market economy. For instance, at the National Bureau of Standards, we work to improve performance prediction and measurement technology. If we make an improvement in the definition of wind loadings and you have a monolithic integrated system, how can you accept that improved definition of wind loadings in the design process? An example of this problem of non-openness may have occured with the Structural Design Language (STRUDL) system. Last fall McAuto advertised that STRUDL has incorporated the 1978 AISC specification. This is a lack of openness; it took five years to make available the updated design criteria because they had to be hard-coded into software.

I have these thoughts and background as I look at the data requirements for the engineering stage. I don't pretend to offer a view of the engineering design process from the viewpoint of an individual designer. What I do offer is a framework that may help in the discussion of data requirements in the engineering stage. I will walk through it quickly, then come back and look at some of the data requirements that occur at the various stages.

THE BASIC PROCESS OF DESIGN

In this process, shown in Figure 5-2, we start with the functional plan, essentially the planning and programming stage discussed by Fred Kitchens in Chapter 4. The functional plan defines what the project is supposed to accomplish in a general sense. From the functional plan, the designer performs a functional analysis to determine what criteria have to be applied in order to achieve the intended function. Conceptual design produces a variety of solution schemes that will meet those functional criteria and fit the functional plan. Environmental analysis leads to a definition of the environment in which each of those schemes would function. A socio-economic analysis leads to the objective functions by which the designer will sort through the various schemes and designs to determine which is best.

A process of integrity analysis follows for each scheme. This is where the designer looks at a particular solution scheme and says: "How can this bugger come apart? What are its failure mechanisms?" For each possible failure mechanism appropriate ultimate criteria are developed to assure a high reliability of successful performance. Then, after considering the various failure mechanisms and the environment, both natural and functional, it's possible to develop the models that will allow you to predict the system's performance.

For each particular scheme, there is the process design where a set of initial proportions is defined. Using the analytical model and the

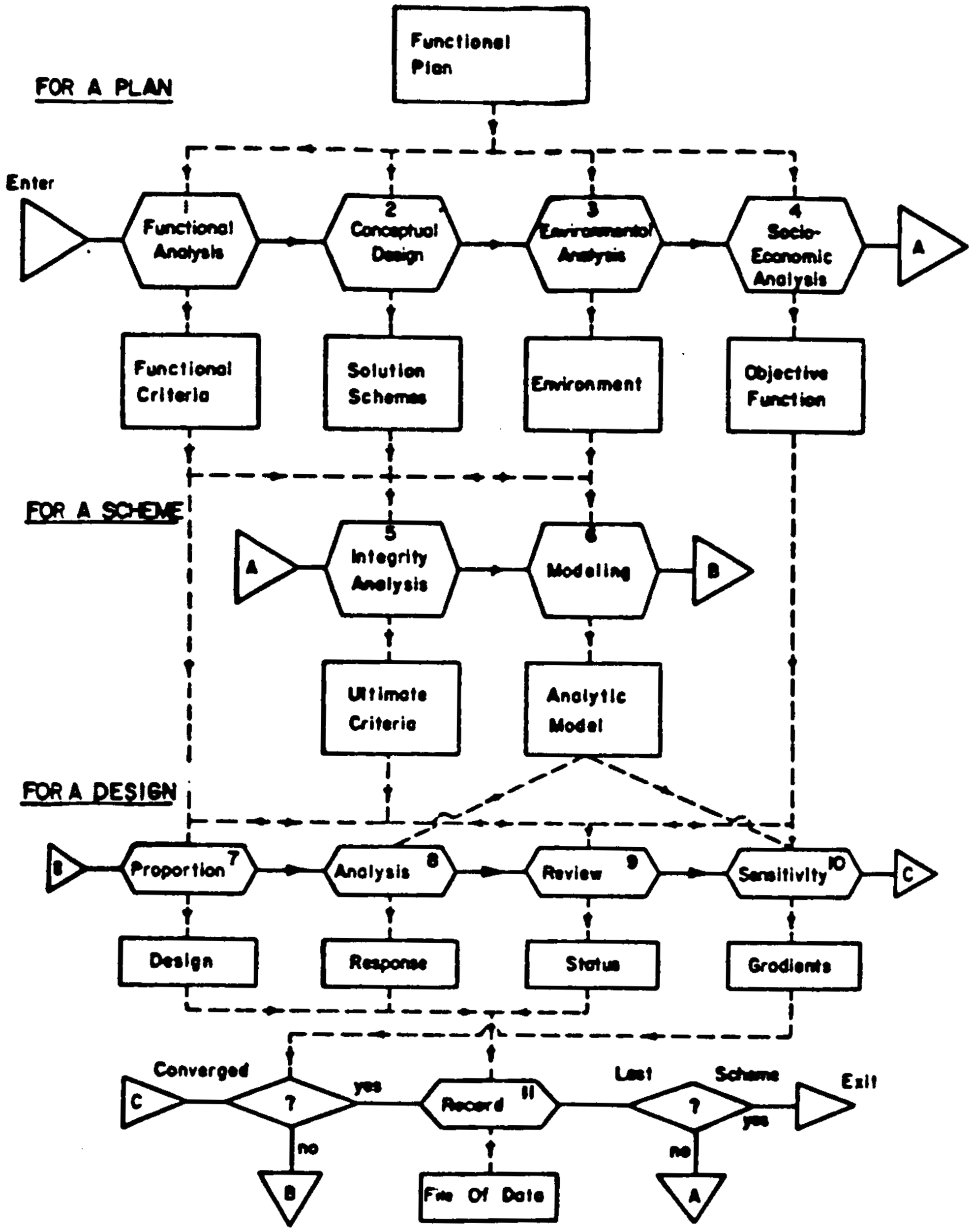

FIGURE 5-2 The basic process of design.

model for the environment, it is possible to determine how the system will respond. That response can be checked against the ultimate criteria and functional criteria to determine the extent to which it is satisfactory or unsatisfactory. Generally, the design is not converged, and the process of sensitivity is considered to determine how changes in the design variables may lead to improvement in meeting the criteria or in meeting the objective function. This is continuously cycled until the design is converged and recorded.

DATA REQUIREMENTS

Having walked through the process, we can address the data requirements that are generated in each stage as shown in Table 5-1. If we look at

TABLE 5-1 Data Requirements at the Engineering Stage

Data Requirements	Input	Output
1. Functional analysis	Generic data base and program plan	Functional Criteria
2. Conceptual design	Program plan, functional criteria, and generic data base	Scheme definition
3. Environmental analysis	Project-specific data base and generic data base	Environment
4. Socio-economic analysis	Project specific data base and generic data base	Objective function
5. Integrity analysis	Scheme solutions and generic data base	Functional and ultimate limitations
6. Modeling simulation	Scheme solutions and generic data base	Performance model
7. Proportion	Project-specific data base and generic data base	Values for design variables
8. Analyze		Response
9. Review		Status of criteria
10. Sensitivity		Test convergence
11. Record		Data file

the functional analysis stage, we need project-specific data from the functional plan as well as generic data that indicate how this type of system should perform.

These data are essential to define the functional criteria. If we look at the conceptual design stage, we need data from the project information system dealing with the functional plan and the results of the functional criteria as well as generic data about how to configure various solutions.

In the environmental analysis stage, we need a great deal of generic or project non-specific data such as how much rainfall we can expect while on Cape Cod. We need data from the project data file to describe the parts of the environment that will be critical in this particular project-specific situation. Again, for socio-economic analysis, a great deal of generic data are required, in addition to project specific data.

During the integrity analysis stage, a large amount of information is required from the project information system. Generic information is required to describe what we know about failure mechanisms and how to provide adequate reliability.

Similiarly, in the modeling stage, the criteria tend to come largely from project information systems but how to model the performance of various types of systems is very much a matter of generic information. By the time we get to the design stage, the participant can work in relative isolation if the criteria, ultimate and functional, describe the amount of "rattle space" available. This is the amount of freedom available to set variables without interferences. There is much interaction, most likely with a local information system rather than a project information system, because the designer has started sketching through various alternatives. The project information system is not needed until we reach a converged design at which point the values that we've set for the significant design variables need to be recorded in the project information system and made available to other participants.

Thus far, I have been talking about this process as if an individual is working in isolation. It is particularly critical at the schematic stage that the design process be integrated because we're talking about fitting together a distribution of functions through space. The architect and the owner carry major roles here. We're talking about how to deliver the proper environment--heating, ventilating, air-conditioning systems, and other services. We're talking about how to fit these things within the structure. Interactive work is needed to assure that the schemes for the various systems can work together.

KEY ISSUES

I would like to cite a few key issues about the engineering interactions with the data base. First, how can we make the project data base support team work? Our engineering jobs are not first rate if all we can do is sub-optimize within a very limited choice of schemes and functional criteria that have been imposed on us from above. Second, how do we provide the proper project to participant data interface? We have real problems about maintaining consistency and integrity. Third, can we be sure that the various pieces of information that participants are using are consistent? How can we do this without locking everybody's hands? Finally, do we provide the kind of interfaces that will support the automated exchanges of data among the participants in the design process?

6

DATA-BASE REQUIREMENTS AT THE ARCHITECTURAL STAGE

Harold Borkin
Professor of Architecture, College of Architecture and Urban Planning
University of Michigan, Ann Arbor

BACKGROUND

I'm a researcher and an architect who's trying to develop computer-aided design in architecture. I will attempt to explain what it is I am trying to achieve and some of the experiments we have been working on over the years. The research method of the group with which I am involved is one of action research as opposed to theoretical research, although, our current work in computer-aided design has a theoretical basis. We don't believe that you should sit in the universities with large groups of researchers and think about things and then write papers that say these are the answers to all your problems. Our mode of work is based on interaction with people and real problems at many scales. I plan to describe to you where we started, what our ideas are, how they are developing, what we're working on now, and what the process is.

Let me first give you an idea about what I think architectural design is. If you strip away all of the mystique of art and science of design, you are left with the idea that design is creative descriptions. You're building a mental model of a building that, at first, may be an extremely private model. Later, you may tell a client about it. You may then tell other people about it. Finally, you have to turn the model into a formalized description that you can give to someone else to build.

It is essentially a question of model building. You start with a set of requirements and conceive a conceptual model. That model grows over time, gets more complex, changes, and transforms itself. What tools do we have to build these models? The conventional tools are those that architects have used for a number of years: certain kinds of drawings and certain kinds of descriptions used to communicate with others. Architects formalize descriptions using certain patterns on which there is universal agreement.

COMPUTER-BASED MODELS

Our research is focusing on the kinds of models that can be built with a computer. Can those models help the design process? If a model is built on a computer, does that model have any characteristics that can help one to design? What kinds of models can be built on a computer that track through the design process? What is the purpose of looking at any design model? The key issue concerns the usefulness of computer-based models. I will explain some characteristics about these models.

First, by building a model of a project on a computer, one should be able to conduct evaluations of the proposed project on the computer and answer the questions: Does it meet the problem? What will its technical performance be? What will its economic performance be? If those questions can be better answered by a computer model than by a paper model, then the design process is aided. The answers to those performance questions are important at any stage in the design process.

The second issue concerns the changing procedures of design: Will this model allow one to use the procedures of iterative design better? Can one generate more alternatives? Can one evaluate them better? Can these things be undertaken without a huge investment? Can one still get the same kinds of information from a computer model as from a paper model?

The third issue concerns iteration versus optimization: Can one use improved design procedures? Can optimization be used, instead of just iteration. Can one ask for and receive the best parts of the design? Is one encouraged to invent different design procedures with the hope of making improvements?

The fourth issue concerns the actual model. Does it support multiple views of the building? Is the model idiosyncratic to the architect or does it allow others to view it in different ways for different reasons. Does it have any life after that the design phase of the project?

These are the four critical issues about building a computer model of a project. While others may have different criteria for deciding on what is necessary for an improved model, I believe if I could address these issues on one model of design, I could produce better buildings.

I have some ideas about how you build these models. While it's difficult to do in detail, the ideas are simple. First, the data base that supports the model does not have to be particularly intelligent, although it must be consistent. The intelligence should originate from the input and output routines that allow users to put data in and get data out. The internal structure of the model can be much more generic and simple.

This idea was a big breakthrough for us. Interfaces, that make things work fine for a particular class of users, should be kept out of the core data base and implemented as a separate input function. These can change depending on the users.

In the beginning we put together a system that had a lot of flaws so that people could experiment with computer modeling. Out of this first experience we found a whole series of mistakes. We mixed up the user functions with the parts of buildings and discovered a whole set of inconsistencies. We learned that there are two characteristics a model must have: (1) it has to be capable of modeling the objects that make up the building, and (2) it has to be capable of modeling the relationships between the objects that make up the building.

What are the objects that make up the building? Architects deal with space, and in the beginning there were not very good models of space for computers. We tried to determine what is a reasonable spatial model. We spent a lot of time looking at data structures before abandoning that approach. Finally, we concluded that we could model space if we could use the mathematical concepts of set theory on spatial models. This allows the operations of union, intersection, and difference to be performed on three-dimensional space.

This development was not an easy process, but the ability to apply set theory to spatial problems turns out to be a powerful tool for real problems. We applied it in complicated problems such as interference problems in a power plant design. We did some practical work on power plant piping using those ideas. We asked if we really wanted to identify everything about the project on a spatial model. It became clear that the space of any object was just an attribute, like its color and weight. Once we realized that the space something occupies is just another attribute, we could deal with any attributes of objects without great difficulty.

We were now able to deal with the relationship between things. Certain things are related by name or part number or function. Others are related by their space, e.g., this is near that or this is far away. You can ask questions about spatial relationships in the same manner that you can ask generic questions. For example, you can ask for all of the elements that are concrete, or all the elements that are concrete in a certain space, or all of the concrete elements that are within 10 feet of each other. These are all spatial issues that have to be supported in a model.

We did develop a simple, experimental modeling system that put these concepts together, and we tried to apply it to some working situations. We built a relational data base that had the concept of relations and domains. Domains are the columns in a relational data base. They are drawn over something that has common values, and they exist across relations. For example, a domain could be a date or a cost. One of the domain types that we developed was that of shape. This could be used to represent the space that something occupied. If an object had a domain that was shape, we had special procedures in order to ask questions about space. We could draw the space, and we could perform set operations on it. We could model things using those attributes by putting space and objects together and asking questions about their relationships.

CONSISTENCY

One interesting area that emerged while developing this model concerned the consistency of data bases. For every domain, a candidacy procedure can be invented so that no value can exist under this domain if it does not meet these criteria. This is one way to assure consistency. For example, if one of the domains of the data base is the starting date of a project and if someone enters a date prior to the starting date, a candidacy procedure would deny entry because that date was before the starting date of the project. While this is a very simple candidacy procedure, elaborate candidacy procedures can be written. For example, you cannot put this object in the data base unless certain other objects are there, or you cannot put this object in the data base if it interferes with another object, or you cannot bolt a copper object to a steel object. Candidacy procedures can be written in any number of ways to keep consistency in the data base.

We performed many experimental projects from nuclear power plant modeling to conventional buildings. What did we discover from this experience? One lesson was that candidacy procedures were very difficult to describe and write. They are specific to the project and are difficult to define. Someone has to ask what are the rules to operate this model. These rules are often not explicit and are usually subject to change.

These domain candidacy procedures are developed from knowledge such as knowing that copper can not be bolted to steel because of an adverse metallurgic reaction. For example, you don't want to develop a rule that no two things can occupy the same space at the same time, even though at first this may seem true. Take the example of a concrete slab that has to have some inserts put in it. The question then becomes: Do we want to deal with the concrete slab minus the inserts plus the inserts, or do we simply want to put the inserts in the concrete slab. It has to do with how we want to think about the problem. We found that there needs to be more research undertaken in the area of maintaining consistency through the rules or the domain candidacy procedures. We need to understand better what goes into the data-base rules.

We also learned that you have to develop special ways of getting data into the model. As we built this model, we chose two editors. One editor allows us to edit relations that look like tables or a spread sheet. The other editor allows us to edit geometries. Describing a fairly complicated building using these editors is no simple matter, but it can be accomplished if the design is nearly complete.

How to design a building with these data-base tools is a difficult and challenging problem. We need to know the dynamics of design development and changes. We are currently working on part of the CAEADS project that uses the idea of a central data base that grows and interacts with a group of users who are trying to design something.* We place much emphasis on the way models are built up. We are looking at a central data base that will allow the use of many analysis tools.

CAEADS involves a fairly simple early description of the building that allows the interface to a number of analysis routines. The

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*Computer-Aided Engineering and Architectural Design System. Sponsored by the U.S. Army Construction Engineering Research Laboratory.

central data base can be used to support a variety of design activities required for the project. It is an evolving system that involves space allocation for concept design in order to get started in the design process.

Some of the data elements are the activities, equipment, finishes, furniture, floors, materials, openings, rooms, stairs, and walls of the project. We capture information about the site and the structural system. These are all integrated and can be used across disciplinary lines.

We are now looking at new ideas about dynamic design and maintaining consistency in the data base. We are attempting an experiment to use a language that models data bases and also models rules with the addition of spatial modeling to see whether we can model an integrated design with that language. We have been working with PROLOG, a language that builds a data base so that the elements of the data base can also be written as rules in the data base. This gives data elements and rules that externally look exactly the same. I don't think it's anything other than an experiment right now. Some people have talked about using this as the basis for design and writing design software. It certainly is a way of experimenting with this idea of rules and data bases.

7

DATA-BASE REQUIREMENTS AT THE CONSTRUCTION STAGE

Jack Enrico
Manager for Cost and Schedule, Bechtel Power Corporation
Norwalk, California

I am going to be pretty basic with what I will tell you about data requirements for construction, and I intend to use my experience with Bechtel to describe how our data requirements for construction evolved. In certain areas we have to adjust to the same issues that have been repeatedly raised at this workshop. In others we are unique because we deal mostly with the contruction of private, rather than government, facilities. For this reason, there are certain things that inherently go into our data base because of the way we are organized and do business.

As you can see in Figure 7-1, we concern ourselves with pre-project, systems planning, site acquisition, and so on. We have worked hard to make the data flow and interfaces work. One of the key points considered when we look at data is the contractural requirements of that project. They have a tremendous effect on the kind of information I will need as a site manager. I have to evaluate the risk involved in what I'm going to construct, and let it determine the information I'm going to need. I also have to consider the extent of my responsibilities and decide what my interface with others will be. Needless to say, these can considerably change my information needs.

At Bechtel, we have developed a data base that accommodates these as well as other factors that influence the content of our data base. Our systems are modular so that we can adjust to the contract form, and we can scale the detail in the system to accomodate our responsibilities. Considerable emphasis has also been placed on identifying data elements critical to our work process and assigning responsibility for their integrity.

PROJECT INFORMATION SYSTEM

Figure 7-2 is a representation of our information system. All of the activities shown in the boxes are computerized. Some of them are interactive, depending on whether we need the response that an interactive system provides. The right side is our "bean counter." It is made up of the day-to-day systems that support the work each of the functions shown perform. As you can see, construction is one of the

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PROJECT DATA BASE SYSTEM DESIRED FUTURE PRACTICE

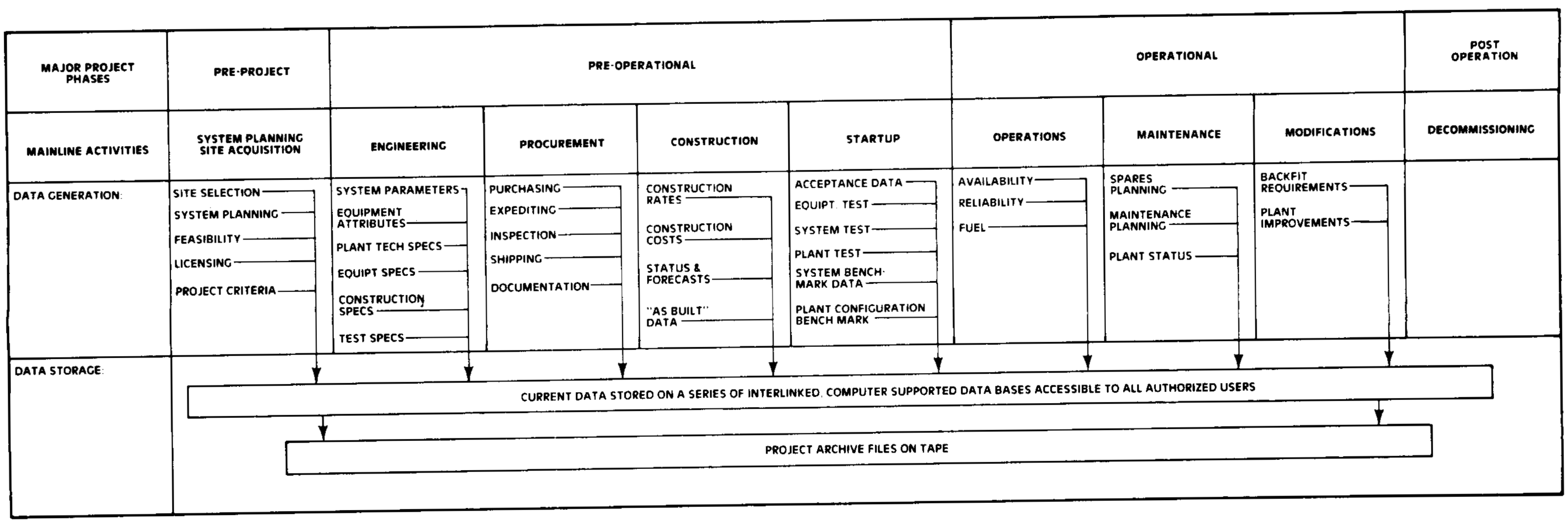

FIGURE 7-1 Project data base system desired future practice.

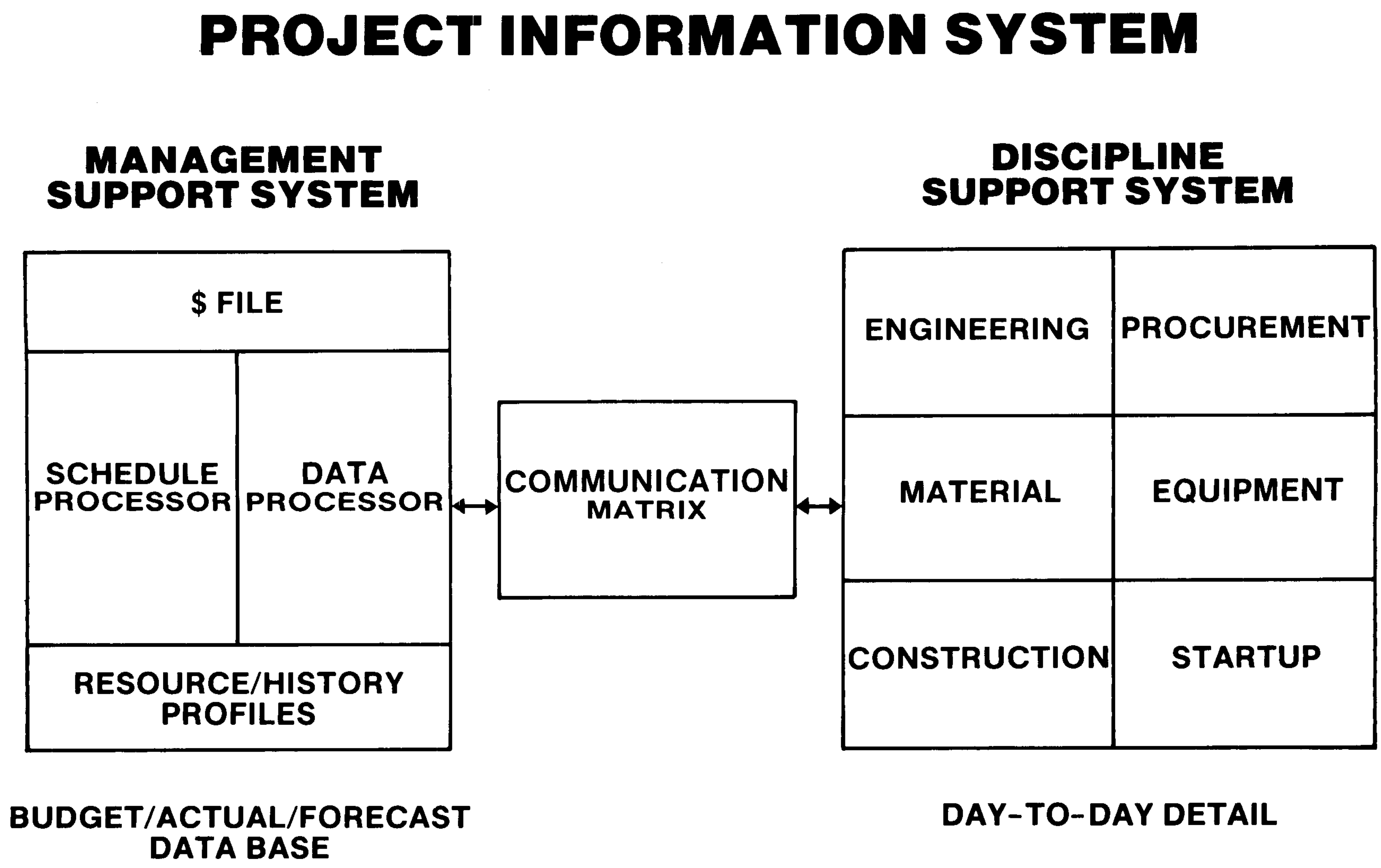

FIGURE 7-2 Project information system.

six functions. The day-to-day systems are interfaced with a sophisticated management information system that integrates all the day-to-day data into project and management reports. The data flow shown in Figure 7-1 is fundamental to this process. Also fundamental are clearly defined user responsibilities as they relate to data integrity. This is because the flow of data from concept through turnover makes the downstream user totally dependent on the timeliness and quality of data provided by his upstream interface. Construction, because of its position in the flow, has the most to lose if data integrity is not maintained.

CONSTRUCTION DATA REQUIREMENTS

It is fairly simple to think about what data is needed in the construction phase (Figure 7-3). As site manager, I just need to know what you want me to build, how much work is involved, and what specific components need to be installed. To do this, you need to tell me when I will receive an installation drawing and when you are going to have the materials delivered. Construction basically deals with descriptions and dates that are provided by others. In most instances, basic data requirements are the same, and the sequence shown in Figure 7-1 will apply regardless of the complexity of the project.

COMMUNICATIONS

Passing information from one phase to another has always been a problem because, to be useful, data must be restructured to fit the requirements of the phase in which they will be used. Figure 7-4 illustrates this problem. For example, engineering designs and information from that design, such as specifications, purchase orders, and vendor drawings, will all be identified in that engineering system. Construction builds by area/volume; therefore, the constructor needs engineering to understand what is intended to be built first, and what materials and drawings will be needed. The data-base numbering system must be structured to accommodate these different requirements, yet do it without destroying the integrity of the engineering or construction individual numbering requirements.

COMPONENT NUMBERING

We expected the problem just described to be difficult to solve, yet found it to be one of the easiest when we considered that contractors build with components, i.e., putting in a light fixture, installing a valve, or laying a piece of pipe. Since components are identifiable, we felt that the component number could provide the common thread through our entire process, and we were right. In our system the component number becomes a part of the system the moment an estimator creates an estimate, the moment a schedule is made, and the moment an engineer begins a design. Obviously, this concept is dependent on a set of very rigid numbers that is carefully specified and understood by everyone.

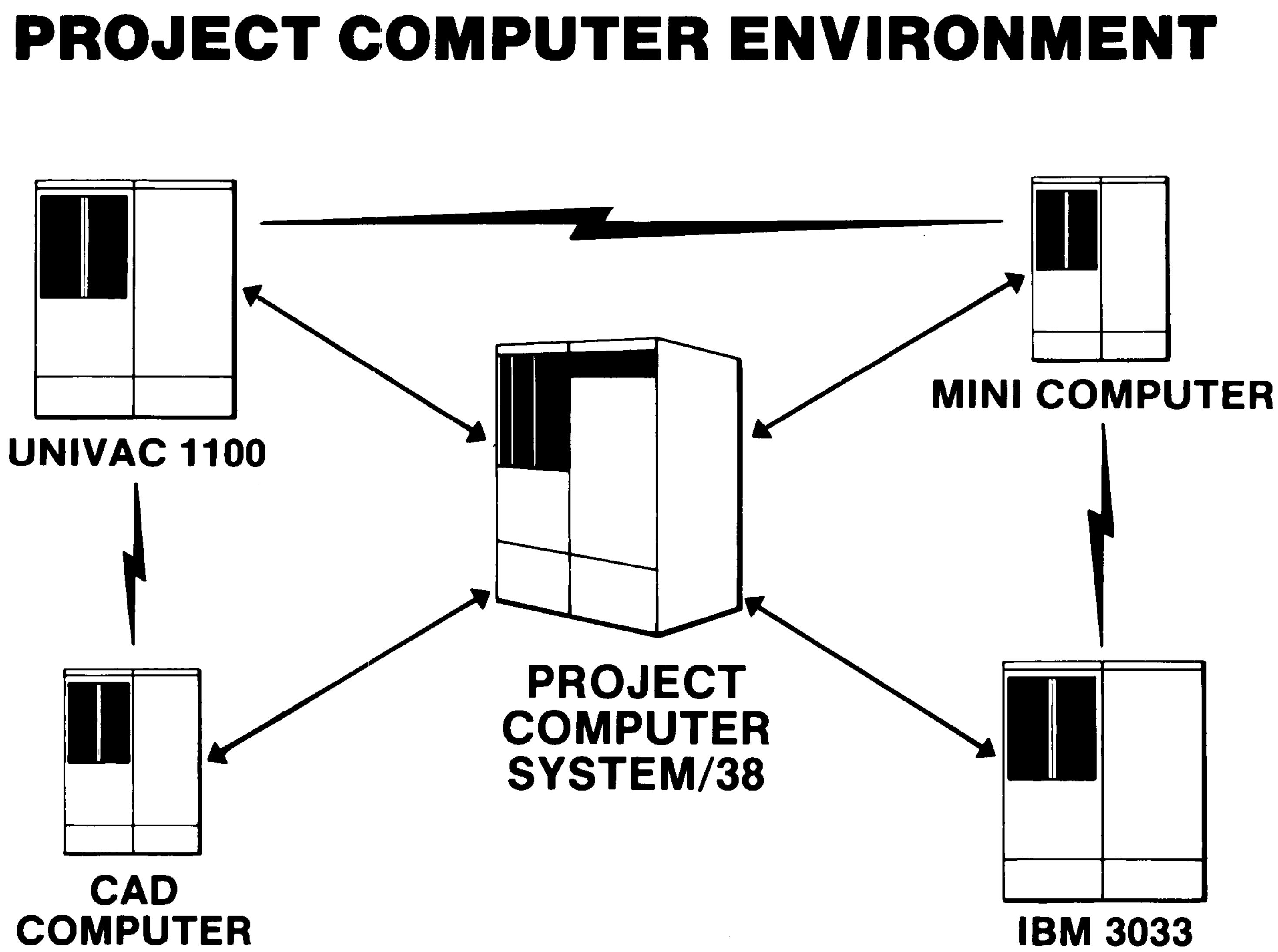

FIGURE 7-3 Project computer environment.

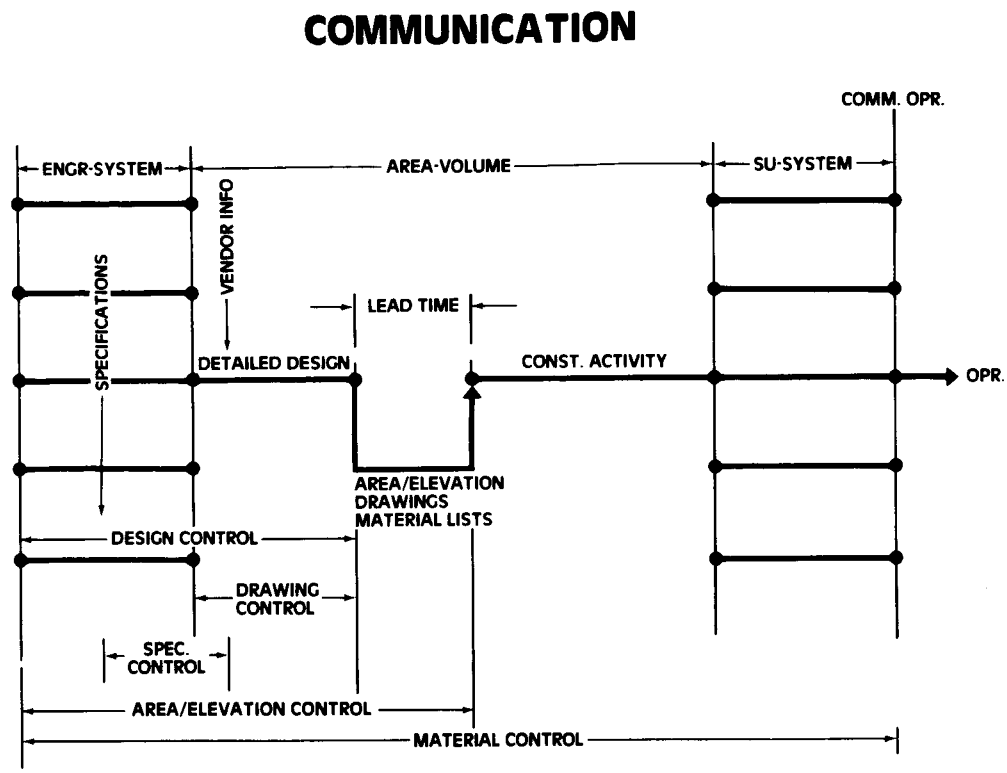

FIGURE 7-4 Communication.

DATA CAPTURE

We are very dependent on a data dictionary in our work because it is a very disciplined system. In the dictionary, data elements are defined and input requirments are specified to insure data integrity. As with all systems, data integrity plays a very significant part in success or failure. Figure 7-5 illustrates how we capture data at the source and at the moment it is originated. At the top are steps required to design, purchase, and install a pump. At the bottom are illustrations of data. In this manner, we actually make the source person responsible for the integrity of his or her assigned data. This approach has vastly improved the quality and timeliness of the data base.

BUILDING A RECORD ILLUSTRATION USING A PUMP AND THE EQUIPMENT SYSTEM

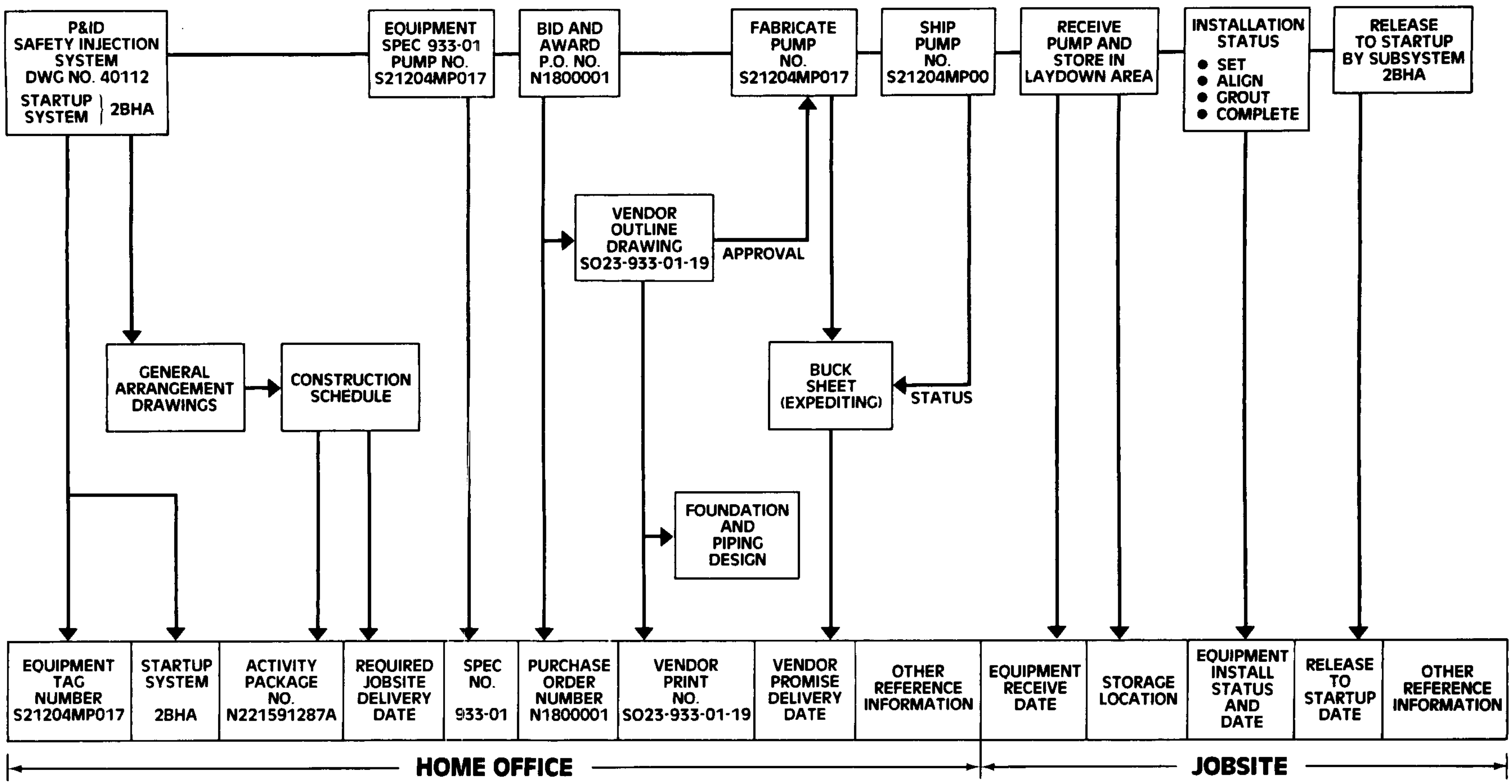

FIGURE 7-5 Building a record illustration using a pump and the equipment system.

CONCLUSION

I have tried to point out some of the major considerations used in our approach to a data base. I have stressed that construction is principally a user of data rather than a generator of data. In that sense, it is totally dependent on the timeliness and quality of data provided by others. It is evident that data capture, data handling, as well as a clear definition of data requirements, are essential to the effective use of a data base in the construction phase.

8

DATA-BASE REQUIREMENTS AT THE FACILITIES MANAGEMENT STAGE

Douglas Nicholson, Senior Vice President
Cushman and Wakefield, New York, New York

I'm an industrial engineer who has spent much time working in the programming phase of the building process. My business does not involve writing the building program as much as writing a long-range real estate program, i.e., telling a company how much and what types of spaces it will need in the future.

Cushman and Wakefield manages over 70 million sq. ft. of space and has a project consulting department that manages real estate projects. The firm helps acquire the land, hires the design team, gives them a program, and manages the design/build process. Cushman and Wakefield owns Building Programs International of which I am chairman. This firm does much research for the International Facilities Management Association (IMFA).

IMFA has completed a recent unpublished study on the management of commercial buildings. I have selected some findings and statistics from that study that I thought would be worthwhile for this group. This study is based on a preliminary analysis of the IFMA data base.

IFMA DATA BASE ANALYSIS

Facility Management Responsibilities

IFMA sent a questionnaire to its members concerning facility management responsibilities. Over 130 responses were received. The respondent group can be described as follows: The average size of facilities is 1.5 million sq. ft., ranging from 22,000 to more than 24 million sq. ft. Typically, facilities management responsibilities are split among two or three groups in the organization. Forty percent of the respondents were in facilities departments; 30 percent in administrative services departments; 10 percent in architecture and design, building services or real estate departments. Facilities-related groups are usually located two or three levels below the vice-president's level. This is usually true regardless of the size of the organization. One of the problems in facilities management is the lack of access to senior management and, consequently, their distance from key decisions about how things are managed. This is, obviously, more a political problem than a data-base problem.

Clusters of Responsibilities

The IFMA study looked at three types of responsibilities called "clusters." These clusters can be described as (1) a space management cluster, (2) a long-range planning cluster, and (3) a maintenance cluster. The three clusters, by definition, are typically done by different groups.

Space Management Cluster The space management cluster of responsibilities is the most complex, and comprises ten main jobs and seven peripheral ones. The ten main responsibilities in this cluster are: initial planning of interiors, replanning, furniture specification, space inventory, space forecasting, space standards, minor changes, major changes, moving crew, and installation crew. The seven peripheral responsibilities, which are related somewhat weakly to the main cluster, are: capital, operations, furniture budgeting, evaluation of design and user satisfaction, furniture maintenance finishes maintenance, and space allocation.

This cluster of responsibilities is usually handled by an administrative services group in small organizations (under 500,000 sq. ft.), by an architecture/design group in medium large organizations (500,000 sq. ft. to 2.5 million sq. ft.), and by a facilities group in very large organizations (over 2.5 million sq. ft.).

Interesting findings about the space management cluster include:

- Major changes and minor changes are often done by different groups.
- The cutoff point between major and minor changes, is in the range of $5,000.
- Furniture budgeting is administratively unrelated to both capital and operations budgeting and is usually done by the group responsible for replanning, space inventory, and furniture specification.
- Capital budgeting, on the other hand, is usually done by the group involved with design and user evaluation or initial planning.
- Operations budgeting is usually done by the group responsible for furniture maintenance. This is the only budgeting process that involves a building services department to any extent.
- Furniture maintenance and maintenance of interior finishes are administratively unrelated to each other.
- Space allocation is largely unrelated to seemingly similar responsibilities such as space standards, design evaluation, and interiors planning.
- Design evaluation and user satisfaction evaluation are done by the same group that does capital planning of interiors.

Long-Range Planning Cluster The second cluster of responsibilities consists of the long-range facility planning functions. Senior management seems to handle long-range planning independently, getting input from multiple groups, but retaining overall responsibility. In the smaller survey, organizations (under 500,000 sq. ft.) reported senior management's involvement most often. In large organizations, senior management is involved mainly in long-range planning and not so often in short and medium long-range planning.

Maintenance Cluster The final cluster of responsibilities can be called maintenance or housekeeping. This cluster consists of housekeeping, trash disposal, preventive and breakdown maintenance, and maintenance of the building shell and grounds.

Interesting findings in this cluster include:

- These responsibilities, more than any other, are contracted out.
- The smallest and the largest organizations do the most contracting. Organizations between 2 and 4.5 million sq. ft. tend to do more of these responsibilities in-house.
- Building services departments are usually involved in all these responsibilities.
- In small organizations, administrative services departments are involved as well.
- In very large organizations, facilities departments, rather than administrative services, are involved.

Summary The picture that emerges is one of some fragmentation of facility responsibilities. Clusters of responsibilities are administratively separated. Some responsibilities that appear to be related, such as different types of budgeting, are often performed by different groups. Nevertheless, in the opinion of the analysts the responsibilities are much more integrated than in a similar survey done four years ago. Further analysis may reveal size or industry-related trends as well.

Staffing

A second questionnaire drew responses from over 100 IFMA members. The "average" respondent's group has a facility-related staff of 11 professionals, 15 tradespeople, and eight support staff. These numbers, of course, vary widely depending on size of the company and how much work is contracted out.

On the whole, the number of professionals on staff is directly related to the square footage of the facilities. The number of tradespeople is much more strongly related to the degree to which services are contracted out than to the number of square feet. The number of support people is related to the degree to which the department has other non-facility responsibilities, implying a sharing of support staff with other functions.

COMPUTER USE IN FACILITY MANAGEMENT

Another questionnaire on computer use sent by IFMA resulted in 252 responses. Although the use of computers varies widely, it is evident that the trend is well-established and growing quickly. I include here some of the highlights of this report.

> The use of computers in facility management appears to be in an early stage of development. Systems in use are, on the average, only 3 years old, and there are many vendors, of which very few are used by more than one respondent. Nevertheless, the use of computers in facility management is fairly widespread, with 41 percent of respondents now using computers and 33 percent planning to do so in the next two years.

Alphanumeric programs, including inventory control and project management, appear to be most important to users as well as the most frequently used applications. Computer use and the number of applications were found to be related to certain organizational characteristics.

What Kinds of Organizations Use Computers for Facility Management?

By using responses to earlier questionnaires, several characteristics of responding organizations were examined to see if they related to the use of computers in facility management. The characteristics were:

- Size of facilities managed;
- Industry type;
- Kinds of facilities managed;
- Use of design standards;
- Facility budget size as a percent of corporate operating expenses;
- Facility expenditures per square foot and per employee;
- Dispersion of facility management responsibility; and
- Facility management workload (number of major and minor work orders).

We also found industry differences. The financial industry (banks and insurance companies) seem to be the slowest to use computers, manufacturing companies generally are future users, and utilities companies have the highest proportion of current users.

INTENT IN PROGRAMMING

At last year's workshop, I noticed that the buzzword most often used was "algorithms." This year, I would like to introduce a new word: "holistic." The major problem I find when I span the entire building process is that a different data base exists for each of the phases. Different data bases, computer-based or otherwise, exist even within discrete segments of the process.

For example, the programming effort is carried out by many people. "Programmers" include the user, the professional programmer, the regulators, and the financiers. The designer, engineer, interior designer, builder, major subcontractors, and fabricator all have a hand in carrying out the original intentions of the program. The programming effort should span the entire building process instead of being prepared by one group and then given over to the designers who may or may not use it effectively.

A number of years ago a learned colleague of mine pointed out that in the field of consulting, of which programming is a category, 90 percent of the accepted consulting reports were never adapted. His reason was that managers, who may have created the problem in the first place, receive a report and can not find anywhere to use it. My business has learned to adopt this lesson in that we do not produce a "program" as an end unto itself. A program is an ongoing thing that evolves out of interaction. You start with a beginning statement of goals, then evolve it and enrich it. The real program is a result of tradeoffs between the mechanical versus structural versus electrical versus design and so on. Just handing over a printed statement of things to be done does not result in a program being followed. Unless the process is interactive, spanning the entire building process, the program probably will not work.

The program must be seen as a developing process. It should get broader and richer, and take in the data that are relevant as it proceeds through the process. By the time one gets to the facilities management phase, a good and complete program should exist. Programming is now concentrated in the front end and is too often ignored. One of the steps to improve data management at the facilities management end of the process is to have that data start off at a minimum basis in the programming stage and build itself through the process until one ends up with, literally, a user's manual.

This user's manual can be a computerized data base, thus easily manipulated. It would add something very few programs ever contain, viz., intent. Intent is not just the result--for example, the HVAC must deliver a certain amount of heat--but includes the rationale and details about who is going to be affected.

Because design of a commercial building involves a team of people through the building process, it is likely that the original program will be bastardized. It is a Murphy's Law in design that if it can be bastardized, it will. Therefore, to ensure better buildings, buildings that respond to their original intentions, a program should start off with a clear description of intention and should have one person responsible for it through the entire process. Original intent can be lost when the programmer is not involved through the entire process.

A program should result from user needs--needs that include community needs, financial needs, life-cycle needs, space requirements, local regulations, and so on--in some type of symbolic representation (models, graphics, drawings or specs). We should have symbolic representation for the program that appear as criteria for things such as use, space layouts, the maintenance of lighting, air conditioning, and so on.

DATA REQUIRED FOR FACILITY MANAGEMENT

The data for facility management must evolve from the original program. They should begin with intent and should build into specific criteria through the building process. Facility design and facility management should evolve from the same data. They are really just different places in the same data base.

There are three major categories of data needs at the facility management stage. These are: (1) basic site information (the building location, general shape and size, and the available utilities), (2) the ownership or lease abstracts, and any unusual requirements for restrictive covenants (such as the requirement that a building can only be four stories in this area), and (3) basic space availability that the user can manipulate.

Data needs include a description and a graphic symbol of the building, the locations of the space, the configuration and dimensioning of each floor, the major permanent core, and the time and legal availability of space (lease ownership abstracts that tell how long one has the space and under what conditions). It should also include current space usage including the partitions (in some graphic representation), ceiling pattern, electrical distribution system, and telephone distribution system. Current space usage by organizational group should include layout, location, personnel inventory by group and the special needs by group, and projected growth changes for the organization, as well as the unit group, on a regularly updated basis.

It should include the ground rules for space usage including layout and standards, and the underlying philosophical intent behind them. This should be tied into those things that are manipulated in the data base (partitions, desks and so on).

There should be some amount of equipment specification data, maintenance guidelines, security guidelines, life safety guidelines, environmental guidelines (acoustics, lighting and so on), information management guidelines, specifications for special areas, and budgeting guidelines.

It is necessary to have the capacity to produce instant working drawings. For example, organizations such as Citicorp in New York are changing so fast that interior design firms have no time to find out about the changes, make the drawings, show it to management for approval, and then make a set of working drawings. By the time this is done, the change has already taken place. These working drawings would be relatively easy to produce coming out of the data base I've been describing.

For me, a data base does not include many things; it is restricted. This list of elements above is adaptable to some sort of graphic symbol. Most of the items can be related to intent where, in the specification, the statement of intent can be introduced. In the facility management stage, then, you end up with a description of what exists, of what is likely to exist organizationally, and the intention or the underlying philosophy of the use of these things.

My view of intent is simply put: I'm going to house certain kinds of people. I have this attitude toward these people in terms of how I want them to interact and deal with one another. I want the environment to support these activities in certain ways. I want to see this intent carried out in the way the building is operated, managed, and used.

PART III

APPENDIXES

APPENDIX I

BIOGRAPHICAL BACKGROUND OF PARTICIPANTS

HAROLD BORKIN is an architect and professor of architecture and urban planning at the University of Michigan. He is director of several computer-aided design research projects for the U.S. Army Corps of Engineers. He is also the director for the development of the ARCH, a model computer-aided design system. Professor Borkin has authored numerous articles and papers on advanced technologies for housing and computer-aided design. He received his bachelor of architecture from the University of Michigan.

ALTON S. BRADFORD is a registered professional engineer and a graduate of the University of Maryland. He is currently the assistant commander for engineering and design at the Naval Facilities Engineering Command (NAVFAC), Washington, D.C. His 25-year career has been dedicated to the design and acquisition of naval shore facilities, structures and systems at the NAVFAC. Mr. Bradford has worked on such projects as Byrd Station, McMurdo Station, and Pole Station, Antarctica; various projects throughout CONUS, Hawaii and Alaska; and many projects in areas such as Spain and Vietnam. During the early 1960s, Mr. Bradford pioneered the use of computers in NAVFAC by employing them in his design work and later by developing and implementing a nationwide computer access system for use by NAVFAC field divisions, including Hawaii.

JAMES H. BURROWS has been the director of the Institute for Computer Sciences and Technology, National Bureau of Standards, Department of Commerce since 1979. The Institute manages the government-wide federal computer standards program, provides technical assistance to federal agencies in the use of computer technology, and conducts related computer science research. These activities are aimed at improving economy and effectiveness in the procurement and use of computers by the federal government. Prior to 1979, Mr. Burrows was associate director, Office of Computer Resources, U.S. Air Force. As the Air Force's senior civilian manager for data automation, he was responsible for developing and implementing policies for ADP management, operations, procurement and standards utilization. Before this he directed the development of large information systems and data management projects for the Mitre Corporation and the Lincoln Laboratory in Massachusetts. Mr. Burrows received his B.S. in engineering from the Massachusetts Institute of Technology in 1949 and his M.S. in mathematics from the University of Chicago in 1951.

JOHN A. COOK is a Research Project Supervisor, Office of Construction, Research Staff, Veterans Administration. From 1960-1967, he supervised construction of VA medical buildings. Since 1967, he has been a member of the Office of Construction Research Staff. Mr. Cook has supervised several projects covering many design and engineering disciplines. Two of the most significant projects have been the Facility Development and Design Review System, an integrated ADP system for the Office of Construction concerned mainly with design review; and the development of the VA Hospital Building System (VAHBS). The VAHBS is now applied to the design and construction of all major new VA hospitals. He is currently supervising a project to develop a prototype nursing home design on a CADD system. Mr. Cook has a Bachelor of Building Construction degree from Auburn University.

LOUIS E. CHILDERS is an architect with the U.S. Postal Service. As Manager, Facility Design Branch, he is responsible for planning, functional design requirements and the selection, technical review and management of contracts with architect-engineer firms performing services for major postal facility projects. Previously, he was a principal in an architectural practice engaged in design of educational and public facilities.

KENNETH H. CRAWFORD is an principal investigator on the Computer-Aided Engineering and Architectural Design System (CAEADS) software development team at the U.S. Army Construction Engineering Research Laboratory in Champaign, Illinois. Currently, he is working on a criteria driven computer-aided design system for use by the Corps of Engineers architects and is involved with training Corps personnel in computer usage. Mr. Crawford has over twenty years experience in software development and has served as a consultant to universities, commercial firms and government agencies. Mr. Crawford has taught mathematics, computer science, computer graphics database design, and data processing courses at Parkland College, Berea College, Illinois State University and Florida State University. He is a visiting professor of architecture at the University of Illinois. Mr. Crawford is a former National Science Foundation Faculty Fellow and has been a Visiting Lecturer for the Mathematical Association of America. He is a co-author of the text "Energy Conservation for the Illinois Home."

C. PATRICK DAVIS has been the chief of the Technical Engineering Branch with the South Atlantic Division of the U.S. Army Corps of Engineers since 1978. In this position he is responsible for planning, organizing, directing and coordinating the work of the mechanical, electrical, structural, hydraulics, environmental, architectural and cost engineering disciplines for a wide variety of Army and Air Force projects and civil works projects in seven southeastern states, Puerto Rico and the Virgin Islands. Mr. Davis is interested in optimum computer system development and utilization for the division and five district offices. Particular areas of current emphasis include cost estimating and design systems to improve design review quality and to shorten design time. He is a registered professional engineer and a graduate of the University of Mississippi and the University of Texas.

H. LAWRENCE DYER is a senior consultant with the Environmental Technology Center for professional services at the Control Data Corporation with responsibility for product development and marketing. Current projects include the design of an integrated computer system for use by water utilities, water management agencies, and their engineering contractors. His past experience includes water resources development at Argonne National Laboratory and environmental engineering for Science Application Inc. Mr. Dyer holds membership in the American Society of Civil Engineers and other honorary and professional societies. He is a mechanical engineer with degrees from Wentworth Institute, the University of Arkansas and Purdue University.

JACK F. ENRICO is manager of cost and schedule for Bechtel Power Corporation's Los Angeles Power Division where he has the responsibility for implementing and administering cost and schedule services on both international and domestic projects. For more than fifteen years he has supervised the development and implementation of automated cost, schedule and material systems for use in the engineering/construction industry. At Bechtel, he has served on a number of related committees including the Computer Applications Committee and as chairman of the Los Angeles Power Division's Project Control Advisory Group. Mr. Enrico is a member of the American Association of Cost Engineers, where he serves as national director for project management; the Project Management Institute; the Los Angeles Council of Engineering Societies; the Planning and Scheduling Study Team of the Business Roundtable; and part-time lecturer at the University of Southern California Graduate School Department of Civil Engineering.

RICHARD H. FIELD is currently deputy assistant commissioner for design and construction at the General Services Administration. Mr. Field has more than 25 years experience in facilities planning, acquisition and management. Prior to joining the General Services Administration, he was a captain in the U.S. Naval Reserve Civil Engineering Corps and a mobilization plan officer in the Naval Construction Force (SEABEES). He received a B.S. in mechanical engineering from the University of New Hampshire and a M.S. in administration from the George Washington University.

ROBERT J. FURLONG has been a civil engineer with the U.S. Air Force on the staff of the Directorate of Engineering and Services since 1982. Prior to this position, he was a project engineer with the Naval Facilities Engineering Command. He is responsible for developing and maintaining civil engineering criteria for all types of Air Force facilities. Mr. Furlong has several years experience in the use of computer-aided design and management information systems. His current interest is in the use of computer systems to manage the design and construction process. He is a registered professional engineer who received his B.S. in civil engineering from Columbia University and his M.S. in geotechnical engineering from the George Washington University.

KENNETH R. GOODWIN is the chief of the Office of Sponsored Programs in the National Engineering Laboratory of the National Bureau of Standards. Prior to this he was associate director for program planning for the National Engineering Laboratory where he was responsible for developing long-range plans and budget proposals for programs in electronics, chemical and manufacturing engineering, building and fire research, and applied mathematics. Mr. Goodwin has also served with the Federal Communications Commission where he established its first long-range policy planning office and developed legislation for the financing of public broadcasting and policy analysis of entrance of cable television into the major markets; as an examiner for commerce science and technology programs with the Bureau of the Budget; as a consultant for Booz, Allen & Hamilton in high technology federal and state government programs; and as science administrator with the Institute for Applied Technology of the National Bureau of Standards. He also has served as a Commerce Science and Technology Fellow to the U.S. Senate Committee on Energy and Natural Resources. Mr. Goodwin has a B.S. in physics from Yale University.

RONALD KING is area manager for design, construction, and building operations and maintenance systems in the General Government Division, Civil Procurement and Property Management Group of the General Accounting Office. Prior to this he was project manager for GAO's study of computer-aided design. Mr. King has a degree in accounting and holds a California CPA certificate.

FRED KITCHENS currently serves as assistant chief, Engineering Division, Savannah District, U.S. Army Corps of Engineers. Prior to this assignment he was chief, Military Program and Management Branch and assistant chief of the Design Branch. Mr. Kitchens has more than 25 years experience in the field of engineering and design, and computer applications in both the technical and managerial areas. He is a registered professional engineer in Georgia and South Carolina and holds a B.S. and M.S. in civil engineering from the Georgia Institute of Technology.

THOMAS KVAN is currently vice president for development with the Computer-Aided Design Group of Santa Monica, California. In this position he is charged with the development of a comprehensive facility space management system based on a centralized data base. Prior to this, Mr. Kvan spent several years as a consultant specializing in the application of computer-aided design and drafting systems in architectural practice. He has also practiced architecture in Asia and Africa. Mr. Kvan was awarded his B.A. at Cambridge, England and his M.A. in architecture at the University of California, Los Angeles. He is currently working on his doctorate at UCLA.

ROBERT E. MAHAN is manager, Computer Systems Support at Battelle Pacific Northwest Laboratories. He is an adjunct lecturer in computer science at the Joint Center for Graduate Study at the University of Washington where he teaches digital design, computer architecture, and data communications. Previous positions at Battelle include manager, Electro-Optics Systems Section and associate manager, Computers and Information Systems Section. His research interests are in the areas of strategic planning, technology forecasting, and management systems. Mr. Mahan received his bachelor and master of science in electrical engineering from Washington State University.

DOUGLAS W. NICHOLSON is senior vice president of Cushman & Wakefield Inc. associated with project development group acting as consultants or managers for development of some major office and mixed use complexes such as the Bank of America, SFO, Sears Tower, Chicago, Petro Canada, Calgary, etc. He is also chairman of Building Programs International, a consulting firm specializing in the development of long range real estate and building programs for such major commercial firms as AMOCO, Citicorp, The World Bank, and Northwest Mutual Life Inc.

MARY OLIVERSON, now with IBM, was president and treasurer of Applied Research of Cambridge, Inc. in Lewiston, New York. She is an architect with experience in housing design, development and construction, and large-scale project planning/predesign. She also has experience in the application of computer techniques to building design, planning and modeling of the built environment including detailed knowledge of computer-aided drafting systems, and computer-aided design systems for architecture, civil and services engineering. Prior to the position at ARC, Ms. Oliverson worked with Skidmore, Owings and Merrill in San Francisco.

FRANKLIN G. PETERS is currently acting director for the policy development division, Office of Project and Facilities Management, with the U.S. Department of Energy. He has expertise in program and project management (including construction management), information system (manual and automated) development and implementation. Mr. Peters holds his B.A. in business management and M.S. in computer/information science.

EDWARD POPKO is with the Graphics System Programming Unit at IBM as software advisor for architectural, engineering and construction CAD/CAM. Since 1971 he has worked extensively with international development agencies to build computer systems for document retrieval, land use planning, and construction management. In 1979 he completed his Ph.D. research at MIT in urban studies and planning and was appointed project director of the Laboratory for Computer Graphics and Spatial Analysis at Harvard Graduate School of Design. At the laboratory, he participated in graphics systems development, taught graduate courses in computer-aided design and continued his personal interest in developing countries with research on microprocessor-based planning systems for low-income housing. Mr. Popko studied architecture at the University of Florida, the University of Detroit and the Massachusetts Institute of Technology.

NEVILLE POWERS is a principal applications engineer with Applicon/Schlumberger, responsible for facilities/plant-layout demonstrations and software support for marketing communications. He joined Applicon in June 1983 after three years with Architectural Science/Computer Modeling (AS/CM) where he was consultant to the U.S. Army Corps of Engineers in the Office of the Chief of Engineers with the Construction Engineering Research Laboratory, and to the Massachusetts Institute of Technology Laboratory for Architecture and Planning. Prior to setting up the AS/CM, he was employed for seven years by Bolt Beranek and Newman Inc. (BBN), where he was a consultant in architectural acoustics, and did research and development work on computer-aided software for graphics and building-analysis applications. He received a B.A. from Bowdoin College and an M.A. in architecture from MIT. He is an author of technical papers in acoustics and computer-aided design, and of primers for new users of computer systems, computer languages, and computer applications.

SHIRLEY RADACK is on the staff of the Institute for Computer Sciences and Technology of the National Bureau of Standards. At the Institute, which provides technical support to the federal government in the management and use of information technology, she is responsible for developing reports, special studies, and analyses of Institute activities. Mrs. Radack has a B.S. in microbiology.

KENNETH F. REINSCHMIDT is vice president and manager for the consulting group at the Stone and Webster Engineering Corporation in Boston. Prior to joining Stone and Webster, he was an associate professor of civil engineering and senior research associate at the Massachusetts Institute of Technology. Dr. Reinschmidt has consulted on problems in construction management, seismic analysis of nuclear piping, project management, and probabilistic fracture mechanics. He has been active in computer-aided engineering and design since 1960 and was associated with the development of such systems as STRESS (Structural Engineering System Solver) at MIT. Currently he is chairman of the Stone & Webster computer oversight computer and sponsors developmental work in computer graphics, CAD/CAM, expert systems, data base applications in engineering, microcomputer applications, financial analysis, and risk analysis. Dr. Reinschmidt received his S.B., S.M. and Ph.D. in civil engineering from the Massachusetts Institute of Technology.

LEONARD SIMUTIS was associate dean for academic affairs, College of Architecture and Urban Studies at Virginia Tech until May 1984. He became the Dean of the Graduate School of Research at Miami University in Oxford, Ohio on July 1, 1984. At Virginia Tech he served as assistant dean and chairman of the Division of Environmental and Urban Studies from 1975-1982, and as director of the Computer Applications Laboratory in the College of Architecture and Urban Studies from 1973-75. He received his bachelor's degree from the University of Illinois, and his M.A. and Ph.D. degrees from the University of Minnesota. His major teaching and research interests are in computer-based approaches to design and planning, with special interest in heuristic approaches employing computer graphics and information systems.

DAVID SKAR is director of the Naval Facilities Engineering Command's Engineering Systems Management Division, responsible for planning, developing and managing the use of advanced technology for engineering and design in Headquarters and its Engineering Field Divisions. This responsibility includes justifying resources, developing requirements for equipment, software, telecommunications and training, and managing system development and installation. These systems support all phases of construction contract document development, criteria development, consultation and management.

ROBERT F. TILLEY, now with Computech, worked with the design and development of computer graphics applications for the Office of Construction of the Veterans Administration. His primary emphasis has been to find ways in which this new technology can aid in the "Design Review" process. In March 1983 his office received approval for a $4.5 million system development effort to automate the design criteria and A/E package preparation functions.

RICHARD N. WRIGHT has directed the National Bureau of Standards' Center for Building Technology, the U.S. national building research organization, since 1974. Its 110 engineers and scientists conduct field, laboratory and analytical research on building practices and on the performance of building materials, components and systems. From 1957-74, he was a member of the civil engineering faculty of the University of Illinois at Urbana. He has conducted research on computer-aided design since 1963. Recent studies focus on advanced methods for the analysis, synthesis and expression of standards and their application in computer-aided design. He was elected President of the International Council for Building Research, Studies and Documentation (CIB) for the 1983-86 term, in which capacity he will host the 10th CIB Triennial Congress CIB.86.

APPENDIX II

National Research Council
Commission on Engineering and Technical Systems
Advisory Board on the Built Environment

SECOND WORKSHOP ON ADVANCED TECHNOLOGY FOR BUILDING DESIGN AND ENGINEERING

National Academy of Sciences Woods Hole Study Center
Woods Hole, Massachusetts
June 17-22, 1984

WORKSHOP SCHEDULE

Sunday, June 17

6:00 PM - 6:30 PM	Registration
6:30 - 7:00	Welcome and Introduction to the Workshop
7:00 - 8:30	Introduction of Participants Self introduction of participants.
	Data Base Design Issues
	General Discussion

Monday, June 18

7:45 AM - 8:30 AM	Breakfast Study Center.
8:30 - 9:00	Introduction to the Day and the Week Carriage House.
9:00 - 10:30	Data Requirements at the Programming and Planning Stage C. Pat Davis and Fred Kitchens, U.S. Army Corps of Engineers. Carriage House.
10:30 - 12:00 Noon	General Discussion

Monday, June 18 (continued)

12:00 - 7:30 PM	Free Time Unstructured time set aside for discussion, relaxation, or exploration of the region. Lunch is provided at the Study Center.
7:30 - 10:00	Working Groups Discussion of subject; establish general principles. A. Interface between Data Sets B. Data Capturing C. Graphics Representation

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Tuesday, June 19

7:00 AM - 8:30 AM	Breakfast Study Center.
8:30 - 9:00	Brief Reports of Evening Sessions
9:00 - 10:30	Data Requirements at the Architecture and Engineering Stage Harold Borkin, University of Michigan and Richard Wright, National Bureau of Standards. Carriage House.
10:30 - 12:00 Noon	General Discussion
12:00 - 6:00 PM	Free Time Lunch is provided at the Study Center.
6:00 - 7:30	Reception and Dinner Cash Bar. Clambake. Study Center.
7:30 - 10:30	Working Groups Formulate critical issues; develop report outline. A. Interface between Data Sets B. Data Capturing C. Graphics Representation

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Wednesday, June 20

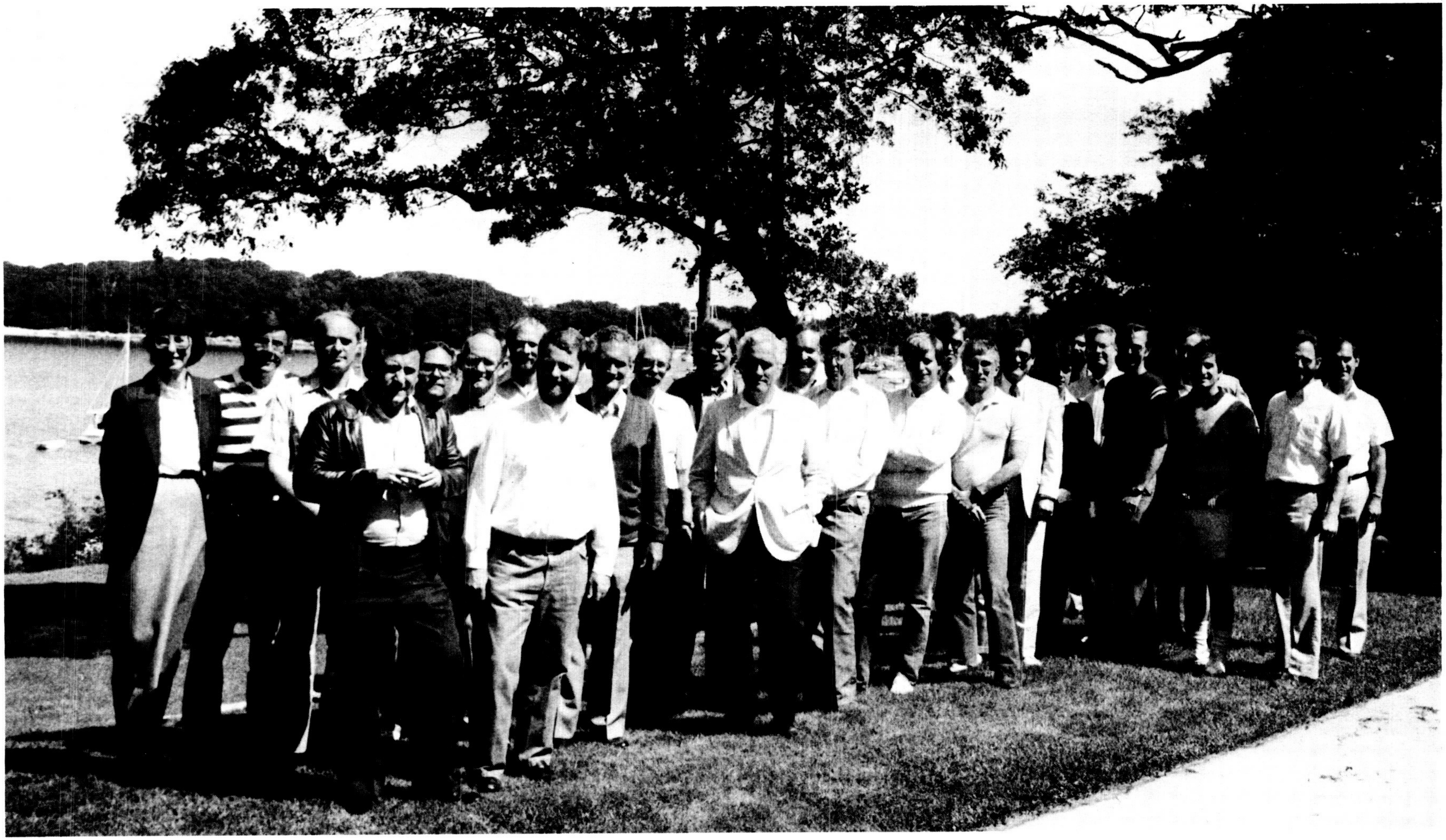
7:00 AM - 8:30 AM	Breakfast Study Center.
8:30 - 9:00	Brief Reports of Evening Sessions
9:00 - 10:00	Data Requirements at the Construction Stage Jack Enrico, Bechtel. Carriage House.
10:00 - 10:30	Coffee Break
10:30 - 12:00 Noon	General Discussion
12:00 - 7:30 PM	Free Time Lunch is provided at the Study Center.
7:30 - 10:30	Working Groups. Discuss critical issues; assign writing tasks. A. Interface between Data Sets B. Data Capturing C. Graphics Representation

Thursday, June 21

7:00 AM - 8:30 AM	Breakfast Study Center.
8:30 - 9:00	Brief Reports of Evening Sessions
9:00 - 10:00	Data Requirements at the Facilities Management Stage Douglas Nicholson, Cushman and Wakefield. Carriage House.
10:00 - 10:30	Coffee Break
10:30 - 12:00 Noon	General Discussion
12:00 - 6:00 PM	Free Time Lunch is provided at the Study Center.
6:00 - 7:30	Reception and Dinner Cash Bar. Cook-out.
7:30 - 10:30	Working Groups Finalize written and verbal reports. A. Interface between Data Sets B. Data Capturing C. Graphics Representation

Friday, June 22

7:00 AM - 8:30 AM	Breakfast Study Center.
8:30 - 12:00 Noon	Reports Working groups present reports in plenary. Carriage House.
	Summary Session
12:00 Noon	ADJOURN Lunch is provided at the Study Center.



1984 Workshop Participants. From left to right: Shirley Radack, Kenneth Reinschmidt, Louis Childers, Robert Mahan, Alton Bradford, C. Patrick Davis, Robert Tilley, Neville Powers, Richard Wright, David Skar, Leonard Simutis, John Eberhard, Richard Field, Harold Borkin, Thomas Kvan, H. Lawrence Dyer, Franklin Peters, Fred Kitchens, Mary Oliverson, Fred Lacerda, Kenneth Goodwin, Ronald King, Kenneth Crawford, Peter Smeallie, Robert Furlong, John Cook. Not pictured are: Jack Enrico, Douglas Nicholson, Edward Popko and Delphine Glaze.